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ABSTRACT

This report presents conditional forecasts of the research talent required for the Canadian government's economic growth and research and development (R&D) targets. A number of alternative scenarios are also assessed. The study limits itself to postgraduate manpower in the natural sciences and engineering. Following an executive summary and introduction, the report focuses on: (1) assessment of the 1985 Gross Expenditures on Research and Development (GERD) and manpower targets; (2) gross national products (GNP) and GERD projections to 1990, considering the growth of GNP, GERN/GNP ratio, and GERD distribution by funder and performer and taking up in turn the 1984 and the adjusted and restructured distributions; (3) highly qualified manpower (HQM) demand projections, considering the 1984 stock of researchers, demand elements (addressing net growth in the stock of researchers, replacements, R&D related demand, and other HQM demand), degree and discipline breakdown, and demand projections; (4) supply of HQM, discussing recent postgraduate growth, forecast of enrollments and degrees, and total annual supply; (5) the gap between supply and demand; and (6) implications arising from the supply/demand analysis, considering occupational mobility, foreign migration, existing programs, and other areas. Included are six appendices with GERD projections to 1990, supporting data for demand and supply projections, and other supporting documentation. (JN)

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Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en genie du Canada

RESEARCH TALENT IN THE NATURAL SCIENCES AND ENGINEERING

Supply and Demand Projections to 1990

(May 1985)

U.S. DEPARTMENT OF EDUCATION
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RESEARCH TALENT
IN THE NATURAL SCIENCES AND ENGINEERING

Supply and Demand Projections

to 1990

(May 1985)

Disponible en français
sur demande

OUTLINE

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EXECUTIVE SUMMARY

This paper presents "conditional" forecasts of the research talent required for the government's economic growth and research and development investment targets. A number of alternative scenarios are also assessed. The study limits itself to postgraduate manpower in the Natural Sciences and Engineering.

According to the model simulations, the forecast supply of research talent would be inadequate to meet the requirements, even with a fairly modest growth in research and development (GERD) expenditures. It would be adequate only under less desirable conditions, such as no, or very slow, economic growth and no further significant increase in the country's (GERD) target.

The imbalances would be more serious in every scenario for certain components of the labour market, such as Applied Scientists and Engineers, new researchers with PhD qualifications, and research talent in specific high demand areas such as Computer Science and Biotechnology.

There is relatively little scope for increasing the supply of postgraduates over a timespan as short as the projection period to 1990. The students who will graduate between now and 1990 either are in postgraduate courses already, or are about to enter from undergraduate studies.

The calculations indicate that the requirements for new postgraduates could be reduced, to a certain extent, by increasing the "productivity" of researchers through such means as improved infrastructure and equipment, more technical support, and by creating career conditions under which researchers would remain in R&D for a longer period. However, while highly desirable in the interest of optimizing scarce resources, neither productivity growth nor a longer R&D career has been the traditional experience during the past decade.

Occupational mobility is not a ready source of supply. There is no surplus of recent postgraduates who could readily move into R&D positions, although there are a few exceptions where retraining could be a possibility. Postgraduates of earlier years who are currently employed in non R&D jobs would not qualify for new research functions requiring state-of-the-art knowledge.

Nor will we be able to rely on immigration. In the high growth disciplines, shortages are world wide. Furthermore, unless there is an improvement in the outlook for R&D jobs in Canada, we run the real risk of losing the already limited talent being trained here to other countries.

The support of research training is an essential "up-front" investment. The lead times for training are so long, and the requirements for any increased science and technology effort so large, that this investment must begin immediately. This is a long-term process requiring a long-term commitment.

For the immediate future, NSERC is proposing further increases in its Undergraduate Summer Research Awards program designed to attract more students to research training. Regarding support of postgraduates, the Council has proposed increases to the Postgraduate Scholarship Program and the Operating Grants Program which would result in support for almost 50% of full-time Canadian students in the fields that are within the Council's mandate by 1990.

The poor financial situation of the universities and the age structure of the existing faculty, make it increasingly difficult for the universities to respond quickly enough to the emerging requirements. To address these structural problems, the Council is strengthening its University Research Fellowship and Industrial Research Professorship program and is proposing a new NSERC Research Professorship program, as well as more support for equipment and infrastructure.

All Council programs are instrumental in training new research talent, because all students, with or without scholarships, benefit from the higher quality scientific environment fostered through NSERC programs.

While the Council's programs are pivotal, they cannot by themselves generate all the new research talent that will be required. New imaginative and nonconventional forms of research training will have to be developed, preferably in cooperation with employers.

In the longer run, a commitment by industry to long-term research, and a restructuring of the reward system in favour of research trained manpower, would have powerful influences on the attitudes of all students towards an R&D career and would, eventually, assure an adequate supply of research manpower.

INTRODUCTION

This paper examines the adequacy of our research manpower resources under various R&D investment paths to 1990, and reviews the role of the Natural Sciences and Engineering Research Coucil (NSERC) in the training of such manpower. It is a background document for the Council's second Five-Year plan. A similar projection was prepared for the first Plan some six years ago (NSERC, 1979).

The government is committed to significantly increasing the level of R&D and the adoption of new technology by industry (Hon. M. Wilson, 1984). However, any major progress in science and technology will be conditional on the availability of highly skilled personnel, and on state-of-the-art training and research facilities at our universities. Even if the emphasis were to be put entirely on the acquisition of foreign technology, we would still need experts who can understand and adapt it, and this would not diminish the demanding manpower challenge that is inherent in any technology push. This paper attempts to identify the potential bottlenecks and to outline the dimensions of the manpower challenge in concrete terms.

Many factors have a bearing on the supply of and demand for manpower. Economic conditions, the attractiveness of R&D investment, the effectiveness and productivity of researchers, the number of years researchers remain in R&D jobs, remuneration, and other factors must be taken into account when estimating the demand for new scientists and engineers. To assure a realistic, as well as systematic, assessment of these factors, a model has been developed that permits testing of any range or combination of plausible assumptions. (Appendix F provides a flow diagram of the underlying model and a sample printout of all the steps in the demand calculations.)

The method used for this study is a development of the approach first applied to the research manpower projections made by NSERC (1979) and MOSST (1981a). In essence, it is an input-output method which relates changes in R&D expenditures to changes in the number of people associated with the research. The approach is akin to that recently developed for more extensive highly qualified manpower studies in Canada (MOSST, 1981b) and in the United States (Scientific Manpower Commission, 1982; and NSF, 1984), which derive manpower demand from output growth of various industry sectors.

The projections are conditional because they are highly dependent on the underlying assumptions. The value of the type of manpower model presented here is not so much its use for overall "manpower planning by numbers", as the fact that it shifts the discussion from the area of numbers into the area of the underlying assumptions and policy objectives. The insights resulting from these projections are intended to assist decision makers - students, universities, companies, and governments. However, the market place and individuals must make the actual decisions, based on perceived opportunities and on their understanding of the signals and government goals.

ASSESSMENT OF THE 1985 GERD AND MANPOWER TARGETS

NSERC's first Five-Year Plan incorporated manpower programs based on the government's 1.5% Gross Expenditures on Research and Development (GERD) target for 1983, later extended to 1985 (MOSST, 1981c). Analysis of the manpower requirements suggested that there would not be adequate supplies of research trained personnel to achieve this target.

The 1985 GERD target will, in fact, not be achieved. According to the most recent GERD data (Statistics Canada, 1984a), in constant dollar terms, GERD increased by only half its planned rate. The biggest shortfall occurred in industrial R&D growth, which advanced by only one-third of the target rate, both in funding and performance. The federal government almost achieved its target growth rate for funding R&D, and research performed directly by the federal government far exceeded the target rate. Consequently, its relative importance as a performer of R&D has increased rather than decreased.

The target vs actual GERD growth rates are summarized in Table 1. The performer and funder distributions are shown in Table 2.

Compared to the original target, research manpower has grown by less than half the projected rate. The actual net increase over the projection period amounted to close to 8,000 researchers, or about one-half the number projected in the first Five-Year Plan. This is consistent with the degree to which the GERD target was realized. During this period, NSERC'S manpower programs were largely responsible for the availability of new researchers, and were instrumental in improving their qualifications.

TABLE 1

1985 GERD Target: Actual vs Plan

		Total % change in constant $ expenditures, 1979-84	
		1.5% Target	Actual
1.	GNP	9.6	7.5
	GERD	61.1	31.3
2.	R&D PERFORMED BY:		
	Federal Government	9.1	37.7
	Provincial Government	29.4	44.9
	Industry	118.0	39.7
	Universities	21.1	8.5
3.	R&D FUNDED BY:		
	Federal Government	41.5	38.6
	Provincial Government	52.8	32.0
	Industry	114.4	32.5
	Universities	0	-5.0

Source. Actual: Statistics Canada (1984a)
Target: MOSST (1981c); and supporting tables.

Note: The target track for 1984 was computed by linear interpolation between 1979and 1985. The GNP data are those consistent with the original 1979 target calculations.

Table 2

GERD DISTRIBUTION, TARGET(1) AND 1984 ACTUAL

	BY PERFORMER			BY FUNDER		
	ACTUAL		TARGET	ACTUAL		TARGET
	1979	1984	1985	1979	1984	1985
Federal Government	24.0	25.1	15.7	36.0	38.1	33.3
Provincial Government	3.7	3.7	2.5	6.8	6.8	6.6
Industry	47.2	50.0	63.0	39.5	40.1	50.0
Universities	24.3	20.0	18.4	12.2	8.8	7.6
Others	0.8	1.1	0.5	5.4	6.2	2.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

(1) MOSST (1981c)

GNP AND GERD PROJECTIONS TO 1990

The second Five-Year Plan of the Council, rather than reacting to a single, narrowly-defined target, tries to get a more complete perspective of highly qualified manpower (HQM) requirements by examining a wide range of plausible scenarios from now to 1990. The scenarios should be seen neither as forecasts as policy options. Their main purpose is to help identify any potential manpower bottlenecks in a more comprehensive and more systematic way than would be possible with a single target.

This report concentrates on the demand for and supply of postgraduate manpower in the Natural Sciences and Engineering, examining a number of factors with a bearing on it, such as the growth rate of GNP, the target GERD/GNP ratio for 1990, the distribution of R&D among the various sectors, the rate at which researchers need to be replaced, and the amount of R&D expenditures per researcher. The assumptions themselves are selected to "bracket" past experience, possible future trends, and policy targets.

The growth of GNP

The volume of GNP, according to the November, 1984 Economic Statement of the Minister of Finance (Hon. M. Wilson, 1984), is projected to grow by 2.4% in 1985, and 3.4% per year thereafter until 1990. This averages to 3.2% per year for the 1984-90 period. Additional simulations are carried out on the basis 0%, 1.1%, 2.2% and 3.7% growth of real GNP.

GERD/GNP ratio

The GERD/GNP ratio assumptions range from an unchanged 1984 ratio of 1.24 to 1.50%, which corresponds to an approximate doubling of today's GERD in current dollars, to 2% which corresponds to an approximate doubling of today's GERD in constant dollars, and 2.5%, which represents a doubling of today's GERD/GNP ratio. The GERD ratio assumptions are for 1990, which is the time frame for the Council's new Five Year Plan. Table 3 and Chart 1 summarize

TABLE 3
GERD PROJECTIONS TO 1990 BASED ON VARIOUS GNP GROWTH AND GERD/GNP RATIO ASSUMPTIONS

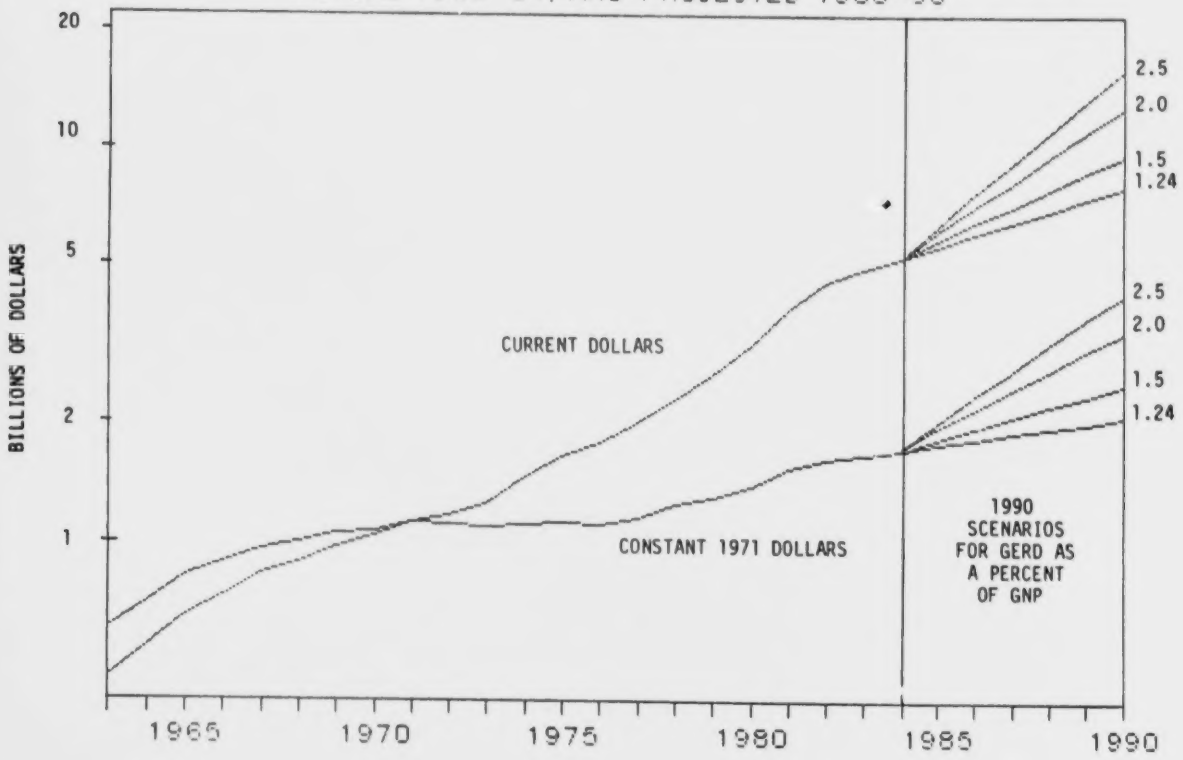
GROWTH RATE OF REAL GNP (ANNUAL AVERAGE, 1984-90)		0%	1.1%	2.2%	3.2%	3.7%
1990 GNP, $MILL, $1984		429,500	458,638	489,405	520,295	534,116
1990 GERD, $MILL., $1984						
GERD/GNP RATIO:	1.24%	5,344	5,687	6,069	6,452	6,623
	1.50%	6,443	6,880	7,341	7,804	8,012
	2.00%	8,590	9,173	9,788	10,406	10,682
	2.50%	10,738	11,466	12,235	13,007	13,353

(1984 GNP = $429,500 MILLION)
(1984 GERD = $5,344 MILLION)

Chart 1

GROSS EXPENDITURES ON R&D IN CANADA

ACTUAL 1963–84, AND PROJECTED 1985–90



the GERD projections to 1990 based on the various GNP growth and GERD/GNP ratio assumptions described above.

GERD distribution by funder and performer

Assumptions are also made about possible changes in the proportion of R&D performed (and funded) by the various R&D sectors, namely the federal government, the provincial governments (including the Provincial Research Organizations), industry, universities, and the "other" sector (mainly nonprofit institutions). Simulation results are based on the following three performer/funder scenarios:

1. The 1984 GERD distribution. The GERD distribution will not change between now and 1990. The complete 1984 distribution is given in Table 5. The GERD projections to 1990 by performing sector based on this distribution and on the above-described GNP growth and GERD/GNP ratio assumptions are given in Appendix Table A-1.

2. The ADJUSTED distribution. The GERD distribution will adjust in a number of ways:

- the growth rate for federal intramural expenditures will be somewhat lower than that for total GERD, implying a reduction of its share in GERD from the present 25.1% to 21% in 1990;

- a similar assumption applies to provincial intramural R&D;

- the federal and the provincial governments' assistance for R&D performed by industry and the universities will rise at the same rate as total GERD;

- industry will have the highest growth rate of any of the sectors for R&D performed and funded;

- industry will increase its contributions to university R&D by a significant margin, as cooperation between the two sectors becomes more intensive;

- R&D performed at the universities will retain its current 20% share in GERD. The share was 24.3% in 1979. Any further decline in the share would weaken the capacity of the universities to provide HQM training and to develop new knowledge and skills, without which the GERD target could not be pursued;

- while university R&D sponsored by external funders will have to rise, the universities themselves will also be required to

Table 4

Real growth in GERD Performer and funder expenditures to 1990

1990 GERD - "ADJUSTED" SCENARIO - ASSUMPTIONS

Growth rates in Real Terms, 1984-1990
(Average annual percentage changes)

Performing Sector

Funding Sector	Fed Gov't	Prov Gov't(3)	Ind.	Univ.	Other(5)	TOTAL
Fed Gov't	9	-	13	12	10	10
Prov Gov't		9	(2)	12	11	13
Industry	-	13	14	(1)	9	14
Univ.	-	-	-	10	-	10
Other(4)	-	-	12	12	11	12
TOTAL	9	8	14	12	11	12

(1) Assumed to rise to $100 million ($ 1984) by 1990
(2) Assumed to rise from $49 million - 1984 to $ 189.9 million in 1990, in constant dollars
(3) Includes provincial research organizations (PROs)
(4) Includes foreign and private non-profit funders
(5) Includes mainly private non-profit performers.

1990 GERD - "RESTRUCTURED" SCENARIO - ASSUMPTIONS

Growth Rates in Real Terms, 1984-1990
(Average annual percentage changes)

Performing Sector

Funding Sector	Fed. Gov't	Prov. Gov't(3)	Ind.	Univ.	Other(5)	TOTAL
Fed. Gov't	0	-	23	14	10	8
Prov. Gov't(3)	-	7	(2)	12	11	8
Industry	-	12	16	(1)	-	17
Universities	-	-	-	8	-	8
Other(4)	-	-	12	12	10	12
TOTAL	0	7	17	12	10	12

(1) Assumed to rise to $112 million in 1984 dollars by 1990
(2) Assumed to rise to $211 million in 1984 dollars by 1990
(3) Includes provincial research organizations (PROs)
(4) Includes foreign and private non-profit funders
(5) Includes mainly private non-profit performers

Source: projections by NSERC
Note: The growth rates in this table are consistent with a 2% GERD/GNP ratio by 1990. The growth rates for the two distribution scenarios at different GERD/GNP targets for 1990 are rescaled accordingly.

generate more R&D support than in recent years. Their ability to do so will be conditional on the type of agreement reached between the federal and provincial governments on R&D cost- sharing in the context of the Established Programs Financing negotiations.

Table 4, ADJUSED scenario, provides the actual growth rates between 1984 and 1990 for each of the R&D expenditure items in the performer/funder matrix for this scenario. Table 5 provides the complete 1990 GERD matrix. The GERD projections to 1990 by performing sector, based on this distribution and the above-described GNP growth and GERD/GNP ratio assumptions are shown in Appendix Table A-2.

3. The RESTRUCTURED distribution. In the third configuration, the GERD distribution will be restructured so that industry will have a significantly larger, and government a significantly smaller role than is now the case:

- Total expenditures for federal government labs will remain at the 1984 constant dollar level. This implies a decline of the GERD share for this activity;

- the federal and provincial governments will raise their industry R&D support significantly to exceed the GERD growth rate;

- industry is assumed to have the highest growth rates for funding and performing R&D of any of the sectors;

- industry will raise its contribtions to university R&D to $112 million by 1990. Provincial sponsorship of university R&D will rise to $211 million;

- it is assumed that R&D performed by the universities will retain its current share of GERD; to do so, internally generated support will have to rise by 8% per year;

- nonprofit organizations will retain their share of R&D performed and funded.

Table 4, RESTRUCTURED scenario, provides the 1984-90 growth rates for each of the R&D expenditure items in the GERD matrix. Table 5 contains the complete matrix for the RESTRUCTURED distribution. The GERD projections by performer, based on this distribution and on the aforementioned GNP growth and GERD/GNP ratio assumptions, are provided in Appendix Table A-3.

TABLE 5

ASSUMPTIONS FOR 1990 GERD DISTRIBUTION BY PERFORMER AND FUNDER

1984 DISTRIBUTION

FUNDER \ PERFORMER	FED. GOV'T	PROV.GOV'T	INDUST.	UNIV.	OTHER	TOTAL
FED. GOV'T	25.15%	0.11%	5.30%	7.41%	0.09%	38.06%
PROV.GOV'T	0.00%	3.35%	0.92%	2.36%	0.17%	6.79%
INDUST.	0.00%	0.24%	39.73%	0.07%	0.06%	40.10%
UNIV.	0.00%	0.00%	0.00%	8.83%	0.00%	8.83%
OTHER	0.00%	0.02%	4.08%	1.35%	0.77%	6.21%
TOTAL	25.15%	3.72%	50.02%	20.02%	1.09%	100.00%

ADJUSTED DISTRIBUTION

FUNDER \ PERFORMER	FED. GOV'T	PROV.GOV'T	INDUST.	UNIV.	OTHER	TOTAL
FED. GOV'T	21.00%	0.00%	5.53%	7.39%	0.08%	34.00%
PROV.GOV'T	0.00%	2.74%	1.77%	2.33%	0.16%	7.00%
INDUST.	0.00%	0.26%	43.77%	0.93%	0.05%	45.00%
UNIV.	0.00%	0.00%	0.00%	8.00%	0.00%	8.00%
OTHER	0.00%	0.00%	3.94%	1.35%	0.71%	6.00%
TOTAL	21.00%	3.00%	55.00%	20.00%	1.00%	100.00%

RESTRUCTURED DISTRIBUTION

FUNDER \ PERFORMER	FED. GOV'T	PROV.GOV'T	INDUST.	UNIV.	OTHER	TOTAL
FED. GOV'T	12.53%	0.00%	9.14%	8.25%	0.08%	30.00%
PROV.GOV'T	0.00%	2.50%	1.97%	2.36%	0.16%	6.98%
INDUST.	0.00%	0.23%	48.70%	1.04%	0.05%	50.02%
UNIV.	0.00%	0.00%	0.00%	7.00%	0.00%	7.00%
OTHER	0.00%	0.00%	3.96%	1.34%	0.68%	5.99%
TOTAL	12.53%	2.73%	63.77%	20.00%	0.97%	100.00%

SOURCE: STATISTICS CANADA (1984a); AND ASSUMPTIONS DERIVED FROM TABLE 4

HQM DEMAND PROJECTIONS

The 1984 stock of researchers

As of 1984 the total research manpower resources amounted to some 28,430 person years (Statistics Canada, 1984a, 1984b, 1984c). This is a "full-time equivalent" estimate, meaning that the number of persons involved is actually higher. Usually, people engaged in research also perform other activities to a certain extent but, for its surveys, Statistics Canada requests research organizations in each of the performing sectors (except the universities) to provide only the full-time equivalent number of scientists and engineers in R&D. For university faculty, the full-time equivalent number of researchers is on an assessment of the percentage of time the average faculty member spends on R&D. There are no comparable estimates about how scientists and engineers divide their time between R&D and other activities for the other sectors.

The aggregate estimate of researchers includes personnel at all three levels of qualification, that is BSc, MSc, and PhD; their approximate proportions can be derived on the basis of occasional survey results over the years. (More on these details and their implications below.) In this study, future HQM demand estimates are limited to the postgraduate portion of the research force, and will exclude estimates for BSc graduates, because supplies of Bachelor-level graduates are considered adequate.

Table 6 shows the number of researchers in the various R&D sectors from 1975 to 1984. From 1975 to 1984, the total number increased by 10,140, with most growth taking place in industry. That sector accounted for 77%, the federal government for 10%, and the provinces and the universities each for 5% of the increase. Chart 2 shows the resulting changes in the distribution of researchers among the five sectors.

Demand elements

The HQM demand estimates to 1990 include the following elements: (1) The net growth of the stock of researchers from 1984 to 1990, implied by the various scenarios. This is the largest demand element, and it varies according to the GNP, GERD scenario, and

TABLE 6
FULL-TIME EQUIVALENT NUMBER OF SCIENTISTS AND ENGINEERS IN R&D
(INCLUDING BScs, MScs, and PhDs; NSE ONLY)

1. NUMBER OF FULL-TIME EQUIVALENT PERSONS

	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
1975	5,050	940	8,320	3,840	140	18,290
1976	5,140	1,020	9,020	3,960	200	19,340
1977	5,120	1,130	9,720	4,030	220	20,220
1978	5,330	1,100	10,520	3,750	250	20,950
1979	5,230	1,180	11,310	4,140	260	22,120
1980	5,250	1,190	12,980	4,210	270	23,900
1981	5,350	1,260	14,640	4,160	320	25,730
1982	5,820	1,500	15,900	4,390	320	27,930
1983(e)	5,940	1,527	16,165	4,387	319	28,338
1984(e)	6,060	1,512	16,093	4,416	349	28,430

2. PERCENTAGE DISTRIBUTION

	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
1975	27.61%	5.14%	45.49%	21.00%	0.77%	100.00%
1976	26.58%	5.27%	46.64%	20.48%	1.03%	100.00%
1977	25.32%	5.59%	48.07%	19.93%	1.09%	100.00%
1978	25.44%	5.25%	50.21%	17.90%	1.19%	100.00%
1979	23.64%	5.33%	51.13%	18.72%	1.18%	100.00%
1980	21.97%	4.98%	54.31%	17.62%	1.13%	100.00%
1981	20.79%	4.90%	56.90%	16.17%	1.24%	100.00%
1982	20.84%	5.37%	56.93%	15.72%	1.15%	100.00%
1983	20.96%	5.39%	57.04%	15.48%	1.13%	100.00%
1984	21.32%	5.32%	56.61%	15.53%	1.23%	100.00%

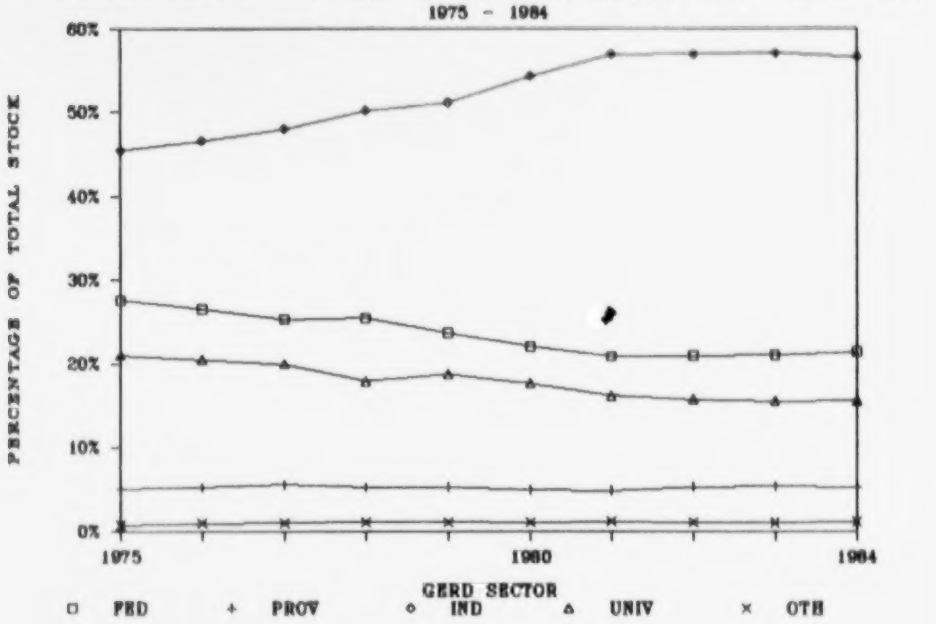
SOURCE: STATISTICS CANADA, "CANADIAN SCIENCE INDICATORS 1983";
"FED. PERSONNEL ENGAGED IN SCIENTIFIC ACTIVITIES 1976 TO 1985";
"INDUSTRIAL RESEARCH AND DEVELOPMENT STATISTICS"

NSE: NATURAL SCIENCES AND ENGINEERING (INCL. HEALTH)

(e) 1983 AND 1984: ACTUAL DATA FOR FED. GOV'T; OTHER SECTORS ESTIMATED ON THE BASIS OF CONSTANT $ GERD AND 1975-82 AVERAGE GERD/RESEARCHER RATIO

Chart 2

DISTRIBUTION OF RESEARCHERS BY SECTOR



productivity assumptions. (2) The replacement needs for researchers who leave research, and who retire or die; this is the second largest demand element, and is a function of the 1984 stock. (3) The demand for researchers arising from R&D related activities (e.g., where there are joint activities such as research and teaching, research and administration, etc.). And (4) demand due to the normal labour force attrition of postgraduates with degrees in the Natural Sciences and Engineering who work in non-R&D occupations.

1. Net growth of the stock of researchers

The net growth to 1990 of the total number of researchers in each sector is a function of the growth in real GNP, the change in the GERD/GNP ratio (i.e., the GERD target), any changes in the distribution of GERD by performing sector, and changes in the GERD/researcher ratio. The range in GNP and GERD assumptions has been discussed in the preceding section.

Changes in the effective amount of expenditures per R&D professional (i.e., in the GERD/researcher ratio) are also used in the the model simulations. The GERD/researcher ratio varies from one sector to the next, but has been fairly constant within each sector since at least 1975. Chart 3 (and Appendix Table B-1) shows this ratio for each of the performing sectors for the years 1975-84. A number of model simulations have been based on assumed increases in this ratio between 1984 and 1990 that might result from more sophisticated equipment and technical staff, even though such increases do not appear to be consistent with the actual experience since 1975.

2. Replacements

The traditional length of the active R&D career of the average researcher has been about 15 years. (NSERC, 1979.) The reasons for leaving are the same as those that usually apply in other occupations: promotion, advancement, change in job, new duties, etc. If this pattern continues, more than one-third of the 1984 stock of researchers will have to be replaced by 1990. A longer R&D career for the average researcher would reduce the need for new people. Simulations of supply-demand are, therefore, also based on a number of longer career assumptions. Table 7 shows the replacement implications for the 1984 postgraduate research force assuming careers lasting up to 30 years. The table shows that 1,260 fewer postgraduate researchers would need to be replaced between now and 1990 if the average career life for all researchers in the stock were to increase from 15 to 20 years. The last column of the table shows the annual reduction in

Chart 3

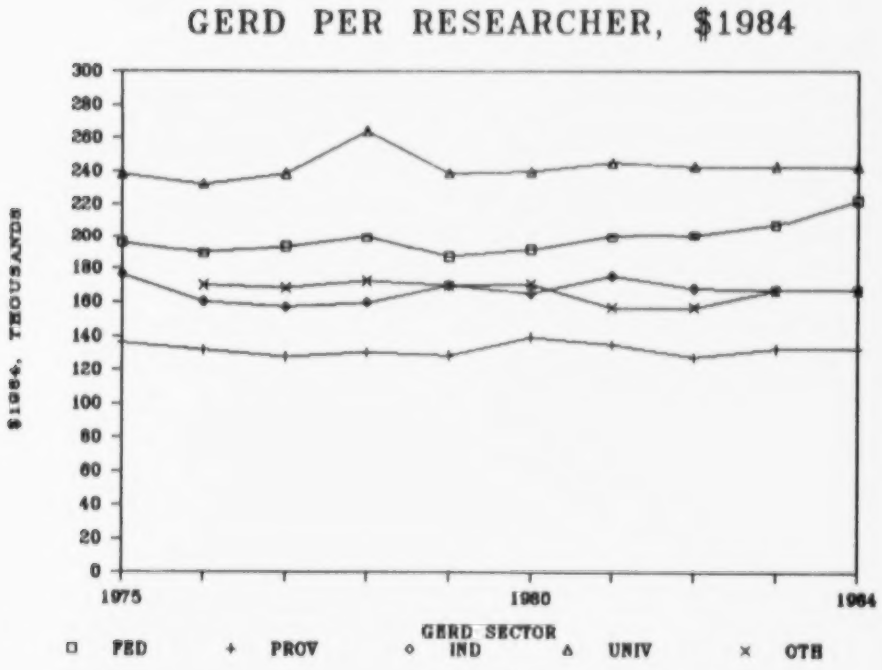

GERD PER RESEARCHER, $1984
$1984, THOUSANDS
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1975
1980
1984
GERD SECTOR
FED
PROV
IND
UNIV
OTH

TABLE 7

SENSITIVITY ANALYSIS OF R&D CAREER-LIFE ASSUMPTION

R&D CAREER LIFE ASSUMPTION (IN YEARS)	ANNUAL REPLACEMENT RATE OF 1984 STOCK	1984 STOCK OF POSTGRADUATES REPLACED BY 1990
5	20.0%	12544
10	10.0%	7966
15	6.7%	5763
20	5.0%	4503
25	4.0%	3693
30	3.3%	3129

replacement need for each one-year increase in the career life for all researchers in the stock. An average of 42 fewer postgraduates would leave research each year if the career life were to rise, for example, from 17 to 18 years.

When it comes to replacement, the universities are now in a different, more difficult situation. Given the serious constraints on new staffing, the replacement assumption has been set at 500, a much lower rate than for the other sectors and, perhaps, too low. However, while in the data on R&D manpower a full-time equivalent university researcher represents about three full-time faculty members, most newly hired faculty during the next few years will likely be in predominantly research rather than teaching positions, so that the traditional one-to-three ratio will not apply to them. Examples of this are the NSERC-supported University Research Fellows (URFs), and the proposed NSERC Research Professors. Nevertheless, the assumption understates the replacement needs to the extent to which such new faculty members perform other duties besides research.

3. R&D related demand

Most researchers do other things besides R&D. In estimating the number of full-time equivalent university researchers, Statistics Canada applies the generally accepted split that professors in the Natural Sciences and Engineering spend about one-third of their time on R&D, and two-thirds on teaching and other related activities. The proportion of time that researchers in the other sectors spend on related activities is probably much smaller, but information on this aspect is not yet available. This study accepts that the need for new full-time equivalent researchers implies a requirement for some additional personnel. It is assumed that, at the Masters' level, 20 additional persons will be required for every 100 identified full-time equivalent R&D positions. At the PhD level, no additional requirements are assumed, implying that new staff will be engaged basically in R&D. This probably results in an understatement of total requirements.

4. Other HQM demand

The other source of HQM demand is the non R&D labour force. According to the most recent survey by Statistics Canada (held in August, 1982), there were 62,000 MScs and 32,000 PhDs with degrees in Natural Sciences and Engineering fields in the labour force, and it is estimated that only about one-fifth of these degree holders work in R&D. The mortality rate for persons in the labour force has been applied to the remaining 75,000, yielding

an annual replacement requirement of 1,250. As PhDs would be in even greater demand for R&D jobs than MScs, the non R&D replacements are assumed to be mostly Masters (1,000 Masters vs 250 PhDs). At best, this is a minimum estimate that barely allows for replacements due to the death rate.

Degree and discipline breakdown

The final step in the demand estimate is to break down the growth, replacement and related requirements by degree and discipline to relate them directly to the supply estimates. This is done for each of the R&D sectors, because each employs a research force with different degree and discipline qualifications. The following information is available for degree qualifications:

-for the federal laboratories, the last survey, which was carried out 10 years ago, indicated that some 45% of the scientists and engineers had PhDs, 25% MScs, and the rest BScs. For the projection period, the ratios are 50%, 30% and 20%.

-the assumptions for provincial government researchers are 30% PhDs, 30% MScs, and 40% BScs (except in the field of Engineering where the assumption is for only 20% PhDs but 40% Masters, reflecting the shortage of Engineering PhDs). This corresponds closely to the 1983 survey results of the Provincial Research Organizations.

-the most recent survey of industrial labs (Statistics Canada, 1984b), carried out in 1982, indicates about 15% of researchers hold PhDs, and 19% Masters degrees: this has not changed significantly from earlier surveys. The relatively low proportion of research-trained personnel reflects that most research undertaken is for short-term, problem-solving applications. To enhance its competitiveness and assure long-term viability, industry will have to make a stronger commitment to long-term research which requires the deployment of highly-qualified, experienced personnel. The projections assume, therefore, that the proportion of Bachelor-level researchers in industry will decline and that of postgraduates increase. This varies by field, as shown in greater detail in Appendix Table B-2.

-it is assumed in the projections that all newly-hired university faculty will be at the PhD level.

-the degree requirements for non-profit organization laboratories

are assumed to be the same as for the provincial laboratories.

Following is the information on field of study distributions:

-The distribution of the Natural Sciences and Engineering faculty in universities is available on a fairly recent basis (Statistics Canada, 1983a). These are the actual and projected distributions:

	Actual 1980-81	Projection 1984-90
Appl. Sciences&Engineering	17.3%	25.0%
Phys. Sciences&Mathematics	30.3%	25.0%
Agric.&Biological Sciences	16.5%	20.0%
Health Professions	35.7%	30.0%

- The distributions will be the same for the federal and provincial labs as for the universities.

- Almost two-thirds of the researchers in industry are trained in Engineering. It is assumed that this will be the proportion required to 1990 as well. Also, a somewhat greater demand for postgraduates in Agricultural and Biological Sciences has been assumed for the period to 1990 - - 6% of the total compared with about 3% a decade ago.

- All new HQM demand for the non profit sector has been assumed to be for graduates in the Health Professions.

(The degree/discipline assumptions to 1990 are summarized in Appendix Table B-2.)

Demand projections

Table 8 shows a range of demand projections based on a large number of combinations of the assumptions discussed above. The table gives only the total NSE estimates for MScs and PhDs, even though the model provides estimates for the four broad sub-disciplines within NSE as well.

The number of required MScs ranges from 1,285 to 3,772 per year under the two extreme sets of assumptions. The low number is generated by assumptions of 0 growth in real GNP, no change in the GERD/GNP ratio, an unchanged 1984 GERD performer distribution by sector (i.e., high government and low industry shares), and a

TABLE 8
SUMMARY OF HQH DEMAND PROJECTIONS BASED ON VARIOUS MODEL SIMULATIONS

GNP AND GERD ASSUMPTIONS			ANNUAL DEMAND FOR NSE POSTGRADUATES, 1984-90					
			LENGTH OF R&D CAREER LIFE ASSUMPTIONS					
			15 YEARS	15 YEARS	20 YEARS	20 YEARS	25 YEARS	25 YEARS
REAL GNP GROWTH 1984-90 %	1990 GERD/GNP RATIO %	1990 GERD PERFORMER/FUNDER DISTRIBUTION (1)	MSes (NUMBER)	PhDs (NUMBER)	MSes (NUMBER)	PhDs (NUMBER)	MSes (NUMBER)	PhDs (NUMBER)
0	1.24	1984 DISTRIBUTION	1,499	723	1,357	611	1,285	556
0	1.50	1984 DISTRIBUTION	1,792	1,104	1,650	992	1,578	947
0	2.00	1984 DISTRIBUTION	2,364	1,848	2,222	1,736	2,150	1,681
0	2.00	ADJUSTED DIST.	2,386	1,773	2,244	1,661	2,172	1,606
0	2.00	RESTRUCTURED DIST.	2,442	1,637	2,300	1,525	2,228	1,470
0	2.00	RESTRUCTURED, PROD.	1,968	927	1,826	815	1,754	760
0	2.50	RESTRUCTURED DIST.	3,034	2,329	2,892	2,217	2,820	2,162
1.1	1.24	1984 DISTRIBUTION	1,591	843	1,449	731	1,377	676
1.1	1.50	1984 DISTRIBUTION	1,908	1,256	1,766	1,144	1,694	1,089
1.1	2.00	1984 DISTRIBUTION	2,520	2,050	2,378	1,938	2,306	1,883
1.1	2.00	ADJUSTED DIST.	2,542	1,969	2,400	1,857	2,328	1,802
1.1	2.00	RESTRUCTURED DIST.	2,602	1,825	2,460	1,713	2,388	1,658
1.1	2.00	RESTRUCTURED, PROD.	2,097	1,066	1,955	954	1,883	899
1.1	2.50	RESTRUCTURED DIST.	3,235	2,563	3,093	2,451	3,021	2,396
2.2	1.24	1984 DISTRIBUTION	1,692	974	1,550	862	1,478	807
2.2	1.50	1984 DISTRIBUTION	2,031	1,415	1,889	1,303	1,817	1,248
2.2	2.00	1984 DISTRIBUTION	2,684	2,263	2,542	2,151	2,470	2,096
2.2	2.00	ADJUSTED DIST.	2,708	2,177	2,566	2,065	2,494	2,011
2.2	2.00	RESTRUCTURED DIST.	2,772	2,023	2,630	1,911	2,558	1,856
2.2	2.00	RESTRUCTURED, PROD.	2,233	1,214	2,091	1,102	2,019	1,047
2.2	2.50	RESTRUCTURED DIST.	3,447	2,811	3,305	2,699	3,233	2,644
3.2	1.24	1984 DISTRIBUTION	1,794	1,107	1,652	995	1,580	940
3.2	1.50	1984 DISTRIBUTION	2,155	1,576	2,013	1,464	1,941	1,409
3.2	2.00	1984 DISTRIBUTION	1,843	1,202	1,701	1,090	1,629	1,035
3.2	2.00	ADJUSTED DIST.	2,874	2,385	2,732	2,273	2,660	2,218
3.2	2.00	RESTRUCTURED DIST.	2,942	2,222	2,800	2,110	2,728	2,055
3.2	2.00	RESTRUCTURED, PROD.	2,369	1,361	2,227	1,249	2,155	1,194
3.2	2.50	RESTRUCTURED DIST.	3,659	3,059	3,517	2,947	3,445	2,892
3.7	1.24	1984 DISTRIBUTION	1,848	1,178	1,706	1,066	1,634	1,011
3.7	1.50	1984 DISTRIBUTION	2,202	1,637	2,060	1,525	1,988	1,470
3.7	2.00	1984 DISTRIBUTION	2,936	2,590	2,794	2,478	2,722	2,423
3.7	2.00	ADJUSTED DIST.	2,962	2,496	2,820	2,384	2,748	2,329
3.7	2.00	RESTRUCTURED DIST.	3,033	2,328	2,891	2,216	2,819	2,161
3.7	2.00	RESTRUCTURED, PROD.	2,441	1,440	2,299	1,328	2,227	1,273
3.7	2.50	RESTRUCTURED DIST.	3,772	3,191	3,630	3,079	3,558	3,024

(1) "ADJUSTED": FED. GOV'T FALLS FROM 25.2% TO 21% OF GERD PERFORMED; INDUSTRY RISES FROM 50% TO 55%.
"RESTRUCTURED": FED. GOV'T FALLS FROM 25.2% TO 12.5% OF GERD PERFORMED; INDUSTRY RISES FROM 50% TO 63.8%.
"RESTRUCTURED, PROD." SAME AS "RESTRUCTURED", BUT GERD/RESEARCHER RATIO RISES 25% (50% FOR UNIVERSITIES)

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quite low replacement rate, based on an R&D career life assumption for the average researcher in the labour force of 25 years (significantly in excess of actual experience).

The high number is generated by a situation in which GNP grows by 3.7% per year (real), the GERD/GNP ratio rises to 2.5%, there is a radical restructuring of GERD away from government and into the private sector, and a replacement rate for researchers is based on the traditional length of R&D career life of about 15 years.

The comparable numbers fo PhDs using the two sets of assumptions range from 556 to 3191.

Special attention is drawn to the scenarios based on a significant increase in "productivity" (i.e., the amount of real expenditures per researcher which is affected by the level of technical support and more sophisticated equipment). The assumption chosen for this test is a 25% increase in productivity for all sectors except the universities, which show a 50% increase. While such an assumption is not realistic in light of actual experience, it serves to illustrate the extent of manpower "savings" that could be realized by raising productivity. The calculations show that with a productivity increase of that size and depending on the level of GNP and GERD activity, the annual demand for MScs would be reduced by about 575 to 600, and that for PhDs by about 700 to 900.

SUPPLY OF HQM

Recent postgraduate growth

Since the beginning of the Council's first Five-Year Plan, there has been a resurgence of interest in postgraduate studies at Canadian universities. In 1983-84, there were 16,345 full-time students enrolled in the Natural Sciences and Engineering (including Health) at Canadian universities, up from 11,216 in 1978-79. Fully one-third of the increase, however, was due to an inflow of foreign (temporary visa) students who, at the end of their studies, must leave Canada. The following table shows the incidence of foreign student growth at the two degree levels:

Growth in NSE Postgraduate Enrolments, 1979 to 1984
(number of students)

	Total	Canadian	Foreign
MScs	3,659	2,691	968
PhDs	1,470	729	741
All Levels	5,129	3,420	1,709

As is evident from this table, the growth of temporary visa enrolments was much stronger at the PhD than at the MSc level -- visa students accounted for over 50% of the increase in PhD enrolments, and 26% of MSc enrolments. In the Applied Sciences and Engineering, a discipline of particular importance to Canadian industry, foreign students made up almost the entire increase (85%) at the PhD level. (Appendix Table C-1 summarizes MSc and PhD enrolments and degrees granted from 1971-84 for each of the four NSE disciplines. Appendix Table C-2 shows the increases in the share of temporary visa students in the various NSE disciplines from 1978-84.)

The main conclusion of this experience is that the supply of qualified Canadian researchers is even more limited than recent postgraduate enrolment growth indicates. It should be noted that the relatively poor participation by Canadians is not because

foreign students occupied places that should belong to Canadians. On the contrary, had it not been for the strength in foreign student participation, many departments would have had difficulty maintaining their graduate programs and research. With the introduction of significantly higher student fees by a growing number of provinces, the growth in foreign enrolments is expected to level off.

Forecast of enrolments and degrees

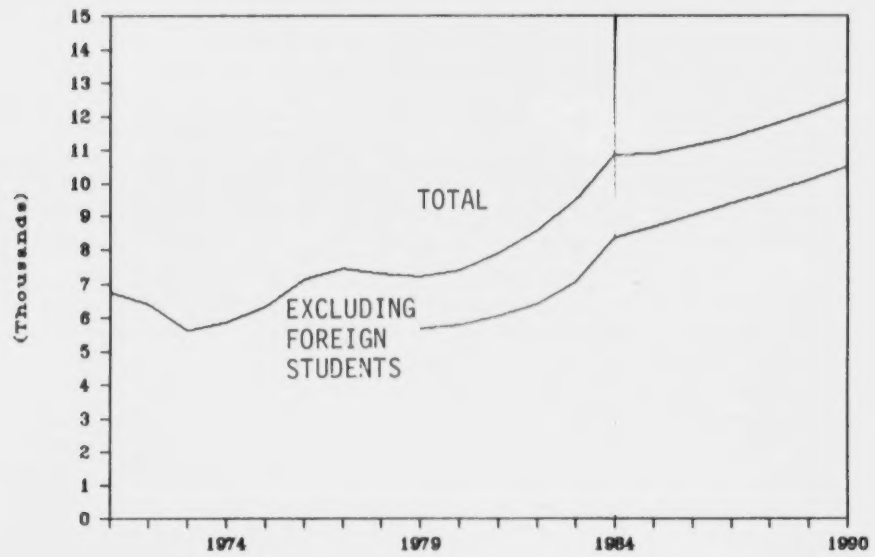
The forecast of postgraduate enrolments and degrees is based on trends in undergraduate enrolments and continued strong interest in part-time postgraduate studies. The growth of the undergraduate student population in the Natural Sciences and Engineering fields peaked in 1982-83, closely following the pattern of the underlying source population. From 1984 to 1990, growth is projected to level off. MSc enrolments, excluding foreign students, are assumed to follow a roughly similar path, with a time lag. In the past, there has been a fairly high and stable correlation between NSE undergraduate enrolments in one year and MSc enrolments one year later. The enrolment data indicate there were 775 MSc students enrolled one year for every 10,000 undergraduate students one year earlier (see Appendix Chart C-1 which depicts this relationship).

The forecast for MSc enrolments to 1990 based on this relationship is shown in Chart 4 (top panel). Participation by Canadians and Permanent Residents is forecast to grow more rapidly than that of foreigners. In particular, visa students at this level are assumed to decline from 2490 in 1984 to 2000 in 1990. Total Canadian full-time MSc enrolments in NSE are forecast to rise from 8,371 in 1984 to 10,523 in 1990 at an average annual growth rate of 3.9% (see Appendix Table C-3 for a more detailed account).

The forecast of MSc degrees granted is also shown in Chart 4 (bottom panel). It is based on the observed relationship with enrolments in earlier years. There is a strong and stable correlation between enrolments one year and degrees granted two years later. According to the data, 4 MSc degrees have been granted in one year for every 10 full-time students enrolled two years earlier during the years since 1970 (see Appendix Chart C-2 which depicts this relationship). As degrees are earned by part-time as well as full-time students, this correlation implies that the proportion of part-time to full-time degree earners has been fairly constant in the past. It is assumed to continue during the forecast period. Total MSc degrees granted to

Chart 4

MSc ENROLMENTS, ALL NSE FIELDS, 1971–90



MSc DEGREES, ALL NSE FIELDS, 1971–90

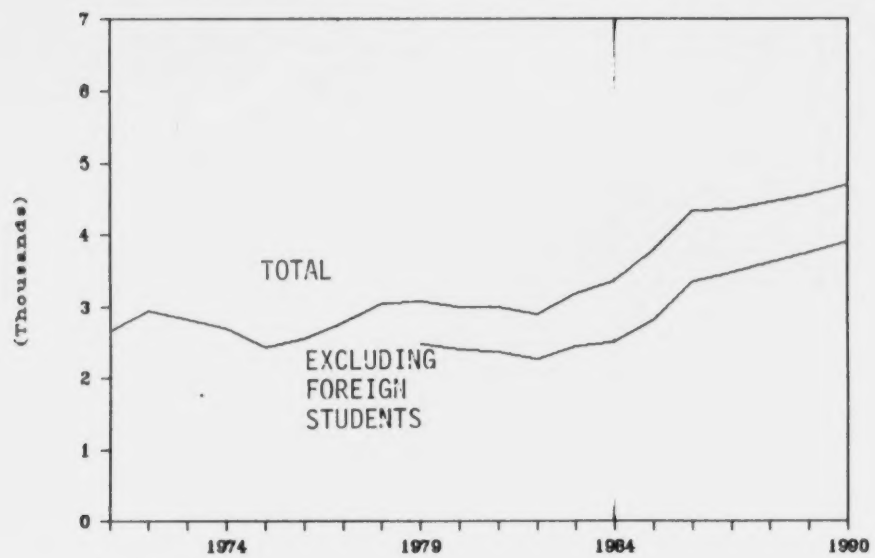
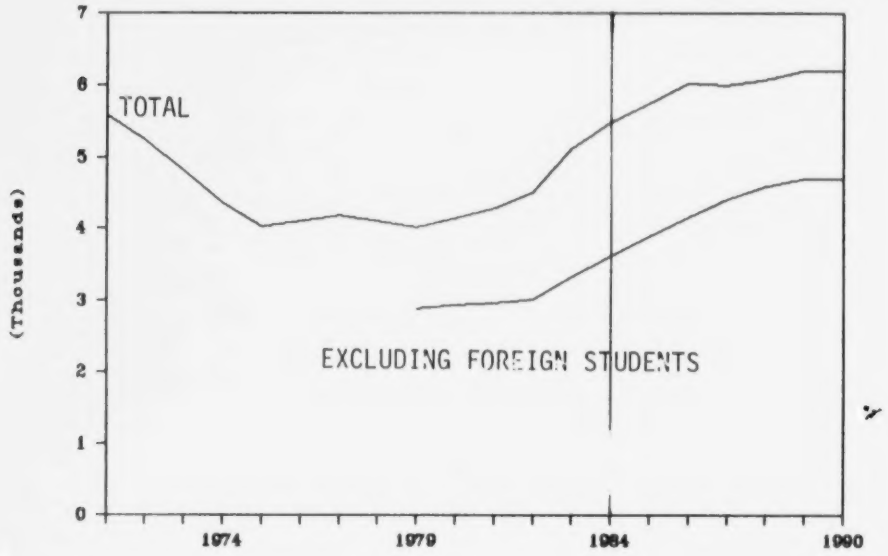
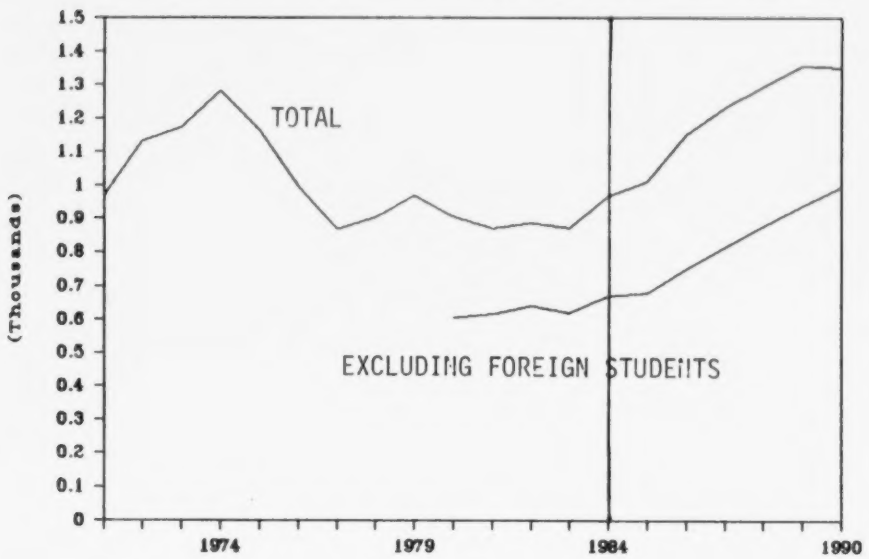


Chart 5

PhD ENROLMENTS, ALL NSE FIELDS, 1971–90



PhD DEGREES, ALL NSE FIELDS, 1971–90



Canadians and Permanent residents are forecast to increase from 2,502 in 1984 to 3,900 in 1990. (See Appendix Table C-3.)

The forecast of PhD enrolments, however, is not based on any direct correlation with degrees granted at the MSc level, because there is no discernible relationship between the two. While a large proportion of Canadian graduates with MSc degrees proceed to PhD programs at Canadian universities, students also come from many other sources: directly from undergraduate programs, postgraduate studies in other countries, and the labour force.

PhD enrolments are forecast to grow at a fairly rapid rate initially, reflecting the recent increases in MSc level enrolments, particularly in Engineering. After growing by 7.5% per year, the growth rate is forecast to decline steadily during the years to 1990. The number of visa students during the next two years is expected to remain at the 1984-85 level of 1,870, and then to stabilize at around 1,500. As shown in Chart 5 (and in greater detail in Appendix Table C-3), PhD enrolments of Canadians and Permanent residents will rise from 3,616 in 1984 to 4,700 in 1990.

PhD degrees granted to Canadians and Permanent Residents are forecast to increase from 670 in 1984 to 994 in 1990. This forecast is based on the correlation between enrolments in one year and degrees granted subsequently. The data indicate that, since 1970, some 22 PhD degrees were granted in one year for every 100 full-time students enrolled three years earlier. The stability of this relationship indicates that the ratio of full-time to part-time students who obtained PhDs was constant during this period. It is assumed that this relationship will continue to 1990. (See Appendix Chart C-3 and Appendix Table C-3 for further details.)

Total annual supply

The postgraduate degrees earned by Canadians and Permanent Residents form the basis for estimating the supply of new researchers that will be available from domestic sources. (The role of immigration is discussed in the section on Closing the Gap, below.) As far as MScs are concerned, it is estimated that some 44% of new graduates will stay in the postgraduate program to study for a doctorate, and will not be available immediately for the labour market. It is assumed that all Canadian PhDs will enter the labour market. (A post-doctoral fellowship is considered to be employment for the purposes of this analysis.) The cumulative 6-year total of postgraduate degrees that will be

Table 9

ANNUAL SUPPLY OF NSE POSTGRADUATES, 1984-90

	Distribution[1]		Number	
	MSc	PhD	MSc	PhD
Natural Sciences and Engineering, Total	100.0%	100.0%	1,952	842
Applied Sciences and Engineering	40.0%	23.5%	906	198
Physical Sciences and Mathematics	24.0%	25.0%	418	295
Agricultural and Biological Sciences	15.0%	25.0%	314	211
Health Professions	18.0%	16.5%	314	139

Source: Estimates by NSERC
(1) see Appendix Table C-4, and Appendix Charts C-4 to C-7

awarded to Canadians is forecast to amount to 26,000. A little over 5,000 of these will be Doctorates and the remainder, almost 21,000, MScs. However, some of the MSc graduates remain in postgraduate studies, and less than three-fifths will actually be available to the labour market. Based on this, the average annual supply of postgraduates in all fields of NSE for the years 1984-90 is 1,952 MScs and 842 PhDs.

These estimates are further broken down by field of study, based on longer-term trends in the enrolment and degree shares of the various fields within total NSE (as illustrated in Appendix Chart C-4). The annual supply of new researchers by degree and discipline is shown in Table 9.

THE GAP BETWEEN SUPPLY AND DEMAND

Overall shortages

The simulation results indicate that there would be overall shortages in virtually all scenarios. Table 10 summarizes the model simulations for 105 combinations of assumptions covering almost every plausible future development for the projection period. Only under conditions very little or no economic growth, and no further increase in the GERD investment target, would the forecast supply be sufficient to meet demand. The shortages would be relatively more serious for PhDs than for MScs.

The calculations show that the supply-demand gap could be reduced by increasing the "productivity" of researchers. Depending on the level of GNP and GERD, for every 1% increase in the amount of real R&D per researcher, there would be a 60-120 reduction in HQM requirements. The table provides results for one set of scenarios with a 25% increase in the level of R&D per researcher over the period to 1990 in all sectors except the universities, and with a 50% increase in the universities. While this assumption is unrealistically optimistic in the light of actual experience, it demonstrates that even with such an assumption, significant shortages would still remain.

Applied Sciences and Engineering

The model provides demand and supply estimates for four broad categories within the total NSE fields. The categories are Applied Sciences and Engineering, Physical Sciences and Mathematics, Agricultural and Biological Sciences, and Health Professions. The imbalances between supply and demand in the various simulations vary significantly among the four broad fields of study. Shortages of both MScs and PhDs would be the most extensive in the Applied Sciences and Engineering, and almost as extensive in the Physical Sciences and Mathematics. In the Agricultural and Biological Sciences, and Health Professions, there would be shortages under almost all scenarios at the PhD level, but supply would be adequate at the MSc level. (A series of charts showing the balances in the four fields under various

TABLE 10
SUMMARY OF SUPPLY-DEMAND DIFFERENCES, BASED ON VARIOUS MODEL SIMULATIONS
TOTAL FOR ALL NSE DISIPLINES

ANNUAL SUPPLY-DEMAND DIFFERENCES TO 1990 (SHORTAGES IN BRACKETS)
TOTAL FOR ALL NSE DISCIPLINES

GNP AND GERD ASSUMPTIONS			LENGTH OF R&D CAREER LIFE ASSUMPTIONS					
			15 YEARS	15 YEARS	20 YEARS	20 YEARS	25 YEARS	25 YEARS
REAL GNP GROWTH 1984-90 %	1990 GERD/GNP RATIO %	1990 GERD PERFORMER/FUNDER DISTRIBUTION (1)	MSes (NUMBER)	PhDs (NUMBER)	MSes (NUMBER)	PhDs (NUMBER)	MSes (NUMBER)	PhDs (NUMBER)
0	1.24	1984 DISTRIBUTION	453	119	595	231	667	236
0	1.50	1984 DISTRIBUTION	160	(262)	302	(150)	374	(35)
0	2.00	1984 DISTRIBUTION	(412)	(1,006)	(270)	(894)	(198)	(89)
0	2.00	ADJUSTED DIST.	(434)	(931)	(292)	(819)	(220)	(76)
0	2.00	RESTRUCTURED DIST.	(490)	(795)	(348)	(683)	(276)	(28)
0	2.00	RESTRUCTURED, PROD.	(16)	(35)	126	27	198	85
0	2.50	RESTRUCTURED DIST.	(1,082)	(1,487)	(940)	(1,375)	(868)	(1,320)
1.1	1.24	1984 DISTRIBUTION	361	(1)	503	111	575	166
1.1	1.50	1984 DISTRIBUTION	44	(414)	186	(302)	258	(247)
1.1	2.00	1984 DISTRIBUTION	(568)	(1,208)	(426)	(1,096)	(354)	(1,141)
1.1	2.00	ADJUSTED DIST.	(590)	(1,127)	(448)	(1,015)	(376)	(986)
1.1	2.00	RESTRUCTURED DIST.	(650)	(983)	(508)	(871)	(436)	(816)
1.1	2.00	RESTRUCTURED, PROD.	(145)	(224)	(3)	(112)	69	(57)
1.1	2.50	RESTRUCTURED DIST.	(1,283)	(1,721)	(1,141)	(1,609)	(1,069)	(1,554)
2.2	1.24	1984 DISTRIBUTION	261	(132)	402	(20)	474	45
2.2	1.50	1984 DISTRIBUTION	(79)	(573)	63	(461)	135	(408)
2.2	2.00	1984 DISTRIBUTION	(732)	(1,421)	(590)	(1,309)	(518)	(1,354)
2.2	2.00	ADJUSTED DIST.	(756)	(1,335)	(614)	(1,223)	(542)	(1,168)
2.2	2.00	RESTRUCTURED DIST.	(820)	(1,181)	(678)	(1,069)	(606)	(1,014)
2.2	2.00	RESTRUCTURED, PROD.	(281)	(372)	(139)	(260)	(67)	(215)
2.2	2.50	RESTRUCTURED DIST.	(1,495)	(1,969)	(1,353)	(1,857)	(1,281)	(1,802)
3.2	1.24	1984 DISTRIBUTION	158	(265)	300	(153)	372	(98)
3.2	1.50	1984 DISTRIBUTION	(203)	(734)	(61)	(622)	11	(567)
3.2	2.00	1984 DISTRIBUTION	(896)	(1,635)	(754)	(1,523)	(682)	(1,568)
3.2	2.00	ADJUSTED DIST.	(922)	(1,543)	(780)	(1,431)	(708)	(1,376)
3.2	2.00	RESTRUCTURED DIST.	(990)	(1,380)	(848)	(1,268)	(776)	(1,213)
3.2	2.00	RESTRUCTURED, PROD.	(417)	(519)	(275)	(407)	(203)	(352)
3.2	2.50	RESTRUCTURED DIST.	(1,707)	(2,217)	(1,565)	(2,105)	(1,493)	(2,050)
3.7	1.24	1984 DISTRIBUTION	104	(336)	246	(224)	318	(169)
3.7	1.50	1984 DISTRIBUTION	(250)	(795)	(108)	(683)	(36)	(628)
3.7	2.00	1984 DISTRIBUTION	(984)	(1,748)	(842)	(1,636)	(770)	(1,581)
3.7	2.00	ADJUSTED DIST.	(1,010)	(1,654)	(868)	(1,542)	(796)	(1,487)
3.7	2.00	RESTRUCTURED DIST.	(1,081)	(1,486)	(939)	(1,374)	(867)	(1,319)
3.7	2.00	RESTRUCTURED, PROD.	(489)	(598)	(347)	(486)	(275)	(431)
3.7	2.50	RESTRUCTURED DIST.	(1,820)	(2,349)	(1,678)	(2,237)	(1,606)	(2,182)

(1) SEE FOOTNOTE FOR TABLE 8

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TABLE 11
SUMMARY OF SUPPLY-DEMAND DIFFERENCES, BASED ON VARIOUS MODEL SIMULATIONS
APPLIED SCIENCES AND ENGINEERING

ANNUAL SUPPLY-DEMAND DIFFERENCES TO 1990 (SHORTAGES IN BRACKETS)
APPLIED SCIENCES AND ENGINEERING

GNP AND GERD ASSUMPTIONS			LENGTH OF R&D CAREER LIFE ASSUMPTIONS					
			15 YEARS	15 YEARS	20 YEARS	20 YEARS	25 YEARS	25 YEARS
REAL GNP GROWTH 1984-90 %	1990 GERD/GNP RATIO %	1990 GERD PERFORMER/FUNDER DISTRIBUTION (1)	MScs (NUMBER)	PhDs (NUMBER)	MScs (NUMBER)	PhDs (NUMBER)	MScs (NUMBER)	PhDs (NUMBER)
0	1.24	1984 DISTRIBUTION	29	2	113	34	155	90
0	1.50	1984 DISTRIBUTION	(146)	(100)	(62)	(69)	(20)	(33)
0	2.00	1984 DISTRIBUTION	(482)	(298)	(398)	(267)	(356)	(251)
0	2.00	ADJUSTED DIST.	(612)	(289)	(534)	(258)	(496)	(242)
0	2.00	RESTRUCTURED DIST.	(839)	(270)	(770)	(239)	(736)	(224)
0	2.00	RESTRUCTURED, PROD.	(549)	(82)	(492)	(53)	(467)	(38)
0	2.50	RESTRUCTURED DIST.	(1,218)	(459)	(1,143)	(428)	(1,106)	(413)
1.1	1.24	1984 DISTRIBUTION	(27)	(31)	56	1	98	16
1.1	1.50	1984 DISTRIBUTION	(214)	(140)	(130)	(109)	(89)	(83)
1.1	2.00	1984 DISTRIBUTION	(573)	(351)	(489)	(320)	(448)	(305)
1.1	2.00	ADJUSTED DIST.	(707)	(342)	(628)	(311)	(589)	(295)
1.1	2.00	RESTRUCTURED DIST.	(941)	(321)	(870)	(290)	(835)	(275)
1.1	2.00	RESTRUCTURED, PROD.	(626)	(120)	(564)	(90)	(535)	(75)
1.1	2.50	RESTRUCTURED DIST.	(1,349)	(523)	(1,273)	(492)	(1,235)	(477)
2.2	1.24	1984 DISTRIBUTION	(87)	(66)	(3)	(34)	38	(19)
2.2	1.50	1984 DISTRIBUTION	(286)	(183)	(203)	(151)	(161)	(136)
2.2	2.00	1984 DISTRIBUTION	(669)	(408)	(586)	(377)	(544)	(362)
2.2	2.00	ADJUSTED DIST.	(807)	(398)	(728)	(367)	(688)	(351)
2.2	2.00	RESTRUCTURED DIST.	(1,050)	(375)	(976)	(344)	(940)	(329)
2.2	2.00	RESTRUCTURED, PROD.	(709)	(160)	(643)	(130)	(612)	(114)
2.2	2.50	RESTRUCTURED DIST.	(1,487)	(591)	(1,410)	(560)	(1,372)	(545)
3.2	1.24	1984 DISTRIBUTION	(144)	(99)	(61)	(68)	(19)	(52)
3.2	1.50	1984 DISTRIBUTION	(355)	(223)	(272)	(192)	(230)	(177)
3.2	2.00	1984 DISTRIBUTION	(761)	(462)	(678)	(431)	(636)	(416)
3.2	2.00	ADJUSTED DIST.	(908)	(454)	(824)	(420)	(784)	(405)
3.2	2.00	RESTRUCTURED DIST.	(1,154)	(427)	(1,008)	(396)	(1,043)	(381)
3.2	2.00	RESTRUCTURED, PROD.	(790)	(198)	(721)	(168)	(688)	(153)
3.2	2.50	RESTRUCTURED DIST.	(1,620)	(656)	(1,542)	(625)	(1,503)	(610)
3.7	1.24	1984 DISTRIBUTION	(174)	(116)	(90)	(85)	(48)	(70)
3.7	1.50	1984 DISTRIBUTION	(391)	(244)	(308)	(213)	(266)	(199)
3.7	2.00	1984 DISTRIBUTION	(809)	(491)	(726)	(460)	(684)	(444)
3.7	2.00	ADJUSTED DIST.	(954)	(479)	(874)	(448)	(834)	(432)
3.7	2.00	RESTRUCTURED DIST.	(1,209)	(454)	(1,134)	(423)	(1,097)	(408)
3.7	2.00	RESTRUCTURED, PROD.	(840)	(222)	(770)	(191)	(736)	(176)
3.7	2.50	RESTRUCTURED DIST.	(1,689)	(690)	(1,611)	(659)	(1,572)	(644)

(1) SEE FOOTNOTE FOR TABLE 9

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selected scenario assumptions is provided in Appendix D.)

Table 11 summarizes the simulation results for the Applied Sciences and Engineering, based on 105 scenario combinations. The forecast level of supply would be adequate under all but the most pessimistic (and least desirable) conditions.

The gap

While the simulations are only broad brush strokes, they clearly indicate that manpower will be a major challenge in the attainment of any future R&D target. If anything, the model assumptions tend to understate the projected imbalances. In relating supply and demand, the model implicitly assumes that the universities generate the mix of research trained graduates within each of the four broad categories that is required on the basis of the demand estimates. However, if the estimates could be broken down into a finer degree of detail by specialization, it would probably be shown that the imbalances are even bigger in a number of specific fields than in the aggregate groupings that had to be used in this model. Examples of specific fields where the shortages would be relatively even larger are Computer Science, Biotechnology, some fields of Engineering, some fields of Forestry, and possibly others.

CLOSING THE GAP

This section looks at the implications arising from the demand-supply analysis. It examines the various possibilities for closing the manpower gap, such as occupational mobility, foreign migration, and the adequacy of existing programs for dealing with the identified shortages. It also discusses the major problems and constraints that now stand in the way of increasing the available research manpower and suggests a number of possible approaches.

Occupational mobility

It is tempting to think of the relatively large number of research trained people in the Canadian labour force as a reservoir of underemployed scientists who could be deployed in new research jobs. Unfortunately, this is not the case, for several reasons.

One is that there are actually fewer persons than would appear at first glance in that pool, who are not in some way already associated with R&D. According to the most recent Statistics Canada survey, there were some 62,000 MScs and 32,000 PhDs with degrees in the Natural Sciences and Engineering in the labour force as of August, 1982. On the other hand, there are over 28,000 full-time equivalent Scientists and Engineers working in R&D jobs. Of these, 20,000 research scientists and engineers are at the postgraduate level of qualification. However, because these are full-time equivalent researchers, the actual number of persons behind the 20,000 is considerably larger. The HQM surveys by Statistics Canada do not collect the data on the research non-research split, but we know that for university faculty the split is about one-third research and two-thirds other activities. This means that the 4,000 university researchers (who are part of the total stock of 28,000) actually represent some 12,000 persons. The amount of non-R&D activity carried out by researchers in the other sectors is probably not as extensive as that in the universities but, nevertheless, the number of people is larger than the number of FTE researchers because of joint activities. Thus, the total pool of NSE postgraduates in the labour force of 94,000 is reduced not by 20,000 but by a significantly larger number, and the size of the potential reservoir is, therefore,

quite a bit smaller than would appear at first glance.

Another reason why occupational mobility is not a major source for new researchers is that NSE postgraduates with degrees obtained in earlier decades and now working in non R&D jobs generally lack the up-to-date knowledge for new research jobs, and are not attracted for economic reasons. They have reached a stage in their careers where they are at senior levels of pay and responsibility. Only the most recent graduates are interested in research jobs, and are considered qualified by employers. According to annual surveys, recent graduates, at least in the NSE fields, have no difficulty finding employment. Of course, not all find research or teaching jobs in their fields, but the majority of those who have received NSERC support tend to stay in research. The pool of underemployed recent graduates, therefore, is not very large, and consists of people with degrees in fields where there is little demand. Selective retraining is a possibility, and a program to address this aspect of the supply situation is proposed in the new Plan of the Council.

A recent study of the US labour market for scientists and engineers came to a similar conclusion (DauffenBach and Fiorito,1983). Occupational mobility is seldom an optimal solution for filling shortages, particularly when a very high degree of skill and knowledge is required, such as in R&D. According to the authors, occupational mobility is a satisfactory source of supply only "if all requirements are filled with experienced and appropriately trained personnel; unless these criteria are met, the general quality of the work force will be diminished. Use of inappropriately trained workers is, in itself, a manifestation of labour market shortage."

Foreign migration

The nature of scientists' activities requires them to be more internationally-oriented than people in most other professions, and migration of scientists can be an important factor in the supply-demand equation. Every year a number of Canadian graduates leaves the country, either to work abroad or to continue their studies. For example, some 10% of NSERC's postgraduate scholarships and one-half of the post-doctoral awards are taken abroad. A recent NSERC survey (Currie, Coopers and Lybrand, 1985) has shown that while a large percentage of NSERC scholars and fellows have studied or worked abroad, only about 15-20% remain abroad for longer terms. There is a net loss of scholars immediately following the completion of their studies, and a net gain after the first position or post-doctoral fellowship. Also,

a number of Canadians obtain their postgraduate training abroad without Council support. The latest data available from US sources indicate that there were 837 Canadian postgraduate students enrolled in the natural sciences and engineering fields at US universities in 1981. (Comparable numbers for 1960 and 1970 were 616 and 959, respectively.) The breakdown between MScs and PhDs is not available, but a reasonable assumption would be 40% in PhD courses. This would generate some 60 to 80 PhDs per year that could potentially return to Canada. However, past experience suggests that about one-half remain in the host country. The number of MSc graduates that is potentially available from this source, while somewhat larger than the number of PhDs, is also not a significant answer to the type of needs indicated in this study.

Immigration has not been a ready, reliable source of skilled manpower for many years. Researchers with strategic skills are in short supply everywhere, and immigration will not be the solution to the shortages described in this analysis. There are no statistics to identify the number of foreign researchers immigrating to Canada or the number of Canadian researchers emigrating to other countries, but it is generally assumed that the flows have slowed to relatively low levels.

Thus, as far as foreign migration is concerned, the model assumes that the inflows and outflows tend to be of the same magnitude at the aggregate level. There may very well be imbalances, positive or negative, for experts in specific fields, or at certain periods of time, but there is no information to derive more precise estimates.

An interesting possibility would be to make it easier for visa students who have obtained a postgraduate degree at a Canadian university to apply for immigrant status, at least for those from developed countries. This could be a very important source of researchers in certain fields such as Engineering, particularly at the PhD level where more than 50% of current enrolments are foreign students.

The question of retaining temporary visa students has already been addressed in the United States, as shown by PhD survey data. Both Canada and the US survey recent PhD graduates to determine employment record, citizenship status, migration, etc. (NRC/NSF, 1983; Statistics Canada, 1985.) Chart 6 relates to the total number of PhDs granted in the two countries in 1983, in all NSE fields. It appears that:

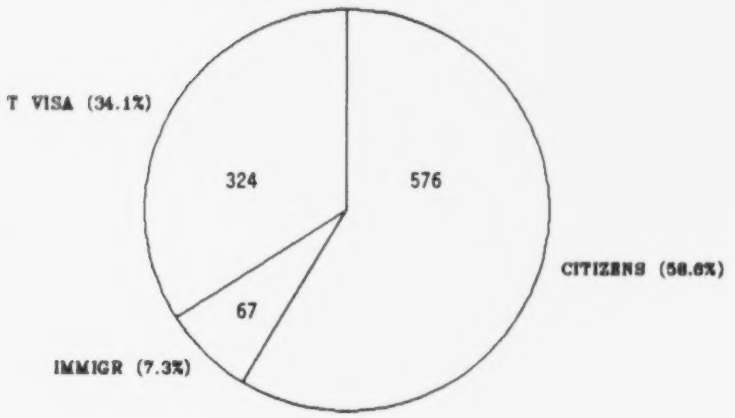
-US universities grant about 13 times as many NSE doctorates as Canadian universities (12,744 vs 967 in 1983);

Chart 6

CANADA: PhDs IN NSE, 1983

% DISTRIBUTION, BY CITIZENSHIP

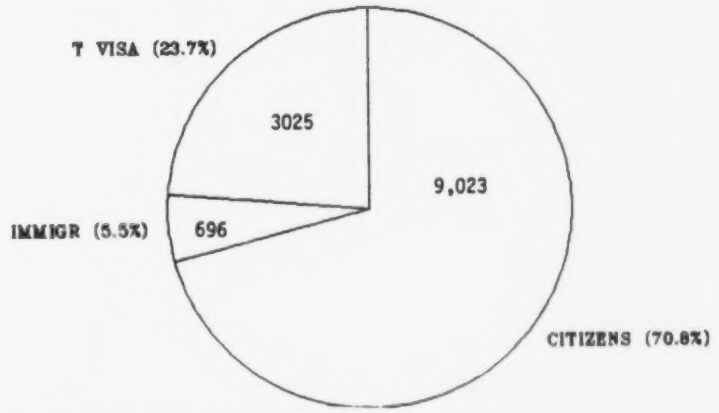
TOTAL NUMBER OF DEGREES GRANTED: 967



US: PhDs IN NSE, 1983

% DISTRIBUTION, BY CITIZENSHIP

TOTAL NUMBER OF DEGREES GRANTED: 12,744



Total number entering U.S. labour market: 11,342 (89%)

-the proportion of degrees earned by foreigners, although high in both countries, is relatively much greater in Canada. Graduates on temporary visas make up 34% in Canada vs 24% in the US;

-in the US, about 89% of all graduates enter the US labour market. This includes temporary visa students who are allowed to remain in the country for another year after graduation under "visa status J" (exchange visitor), after which they may obtain, in areas of high demand, an "H visa" (temporary worker). The proportion of foreigners allowed to remain at least for another year or two is even higher because not all of the 11% who leave the country after graduation are foreigners. The visa extension has the immediate benefit of increasing the size of the US research force, and creates contacts and opportunities for eventual permanent employment;

-the Canadian annual PhD survey shows that 35% of NSE graduates take up employment (including tenure of a postdoctoral fellowship) in another country after graduation. However, the response rate to the survey is no more than 70%, and graduates on temporary visas are under represented in the response. As such graduates are normally obliged to leave Canada after completion of their studies, this implies an even larger proportion of PhDs leaving Canada than is indicated in the survey;

-on this basis, the number of PhDs available for the US labour market appears to be at least 20 times as large as the number in Canada.

The comparison for PhDs in Engineering is even less favourable. Chart 7 compares Engineering PhDs granted in 1983. It appears that:

-US universities grant about 13 times as many Engineering PhDs as Canada;

-the proportion of foreign students on temporary visas is extremely high in both countries: 46% in the US, 50% in Canada;

-86% of the Engineering graduates from US universities enter the US labour market. This includes tenure of post-doctoral fellowships by US citizens as well as foreigners on temporay visas;

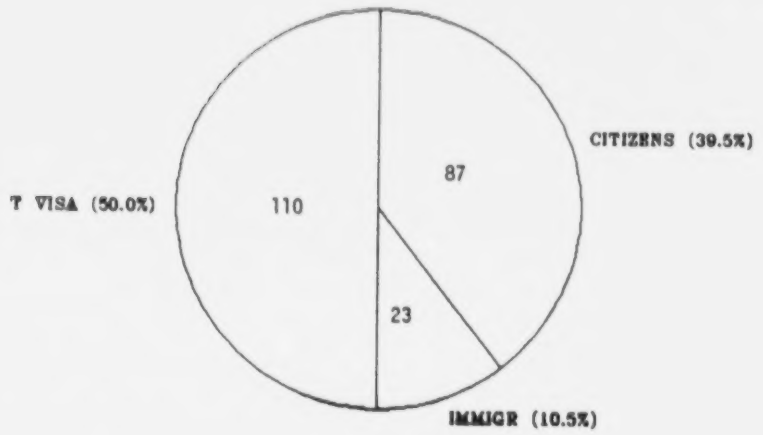
-due to the low response rate to the Canadian PhD survey, the proportion of Canadian Engineering PhDs who enter the Canadian labour market cannot be precisely determined. The survey indicates that 60-70% remain in Canada, either for employment or to take up a post-doctoral fellowship, but given the lower response rate by foreign graduates (who normally leave the

Chart 7

CANADA: PhDs IN ENGINEERING, 1983

DISTRIBUTION BY CITIZENSHIP

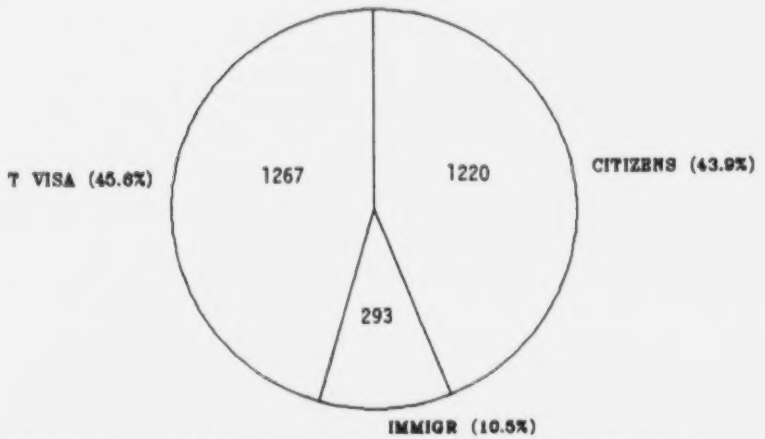
TOTAL NUMBER OF DEGREES GRANTED: 220



US: PhDs IN ENGINEERING, 1983

DISTRIBUTION BY CITIZENSHIP

TOTAL NUMBER OF DEGREES GRANTED: 2780



Total number of PhDs entering U.S. labour market: 2391 (86%)

country after graduation), the percentage remaining in Canada is even lower;

-on this basis, it appears that the US/Canada ratio is even higher than 20 to 1 in the case of Engineering PhDs.

Existing programs

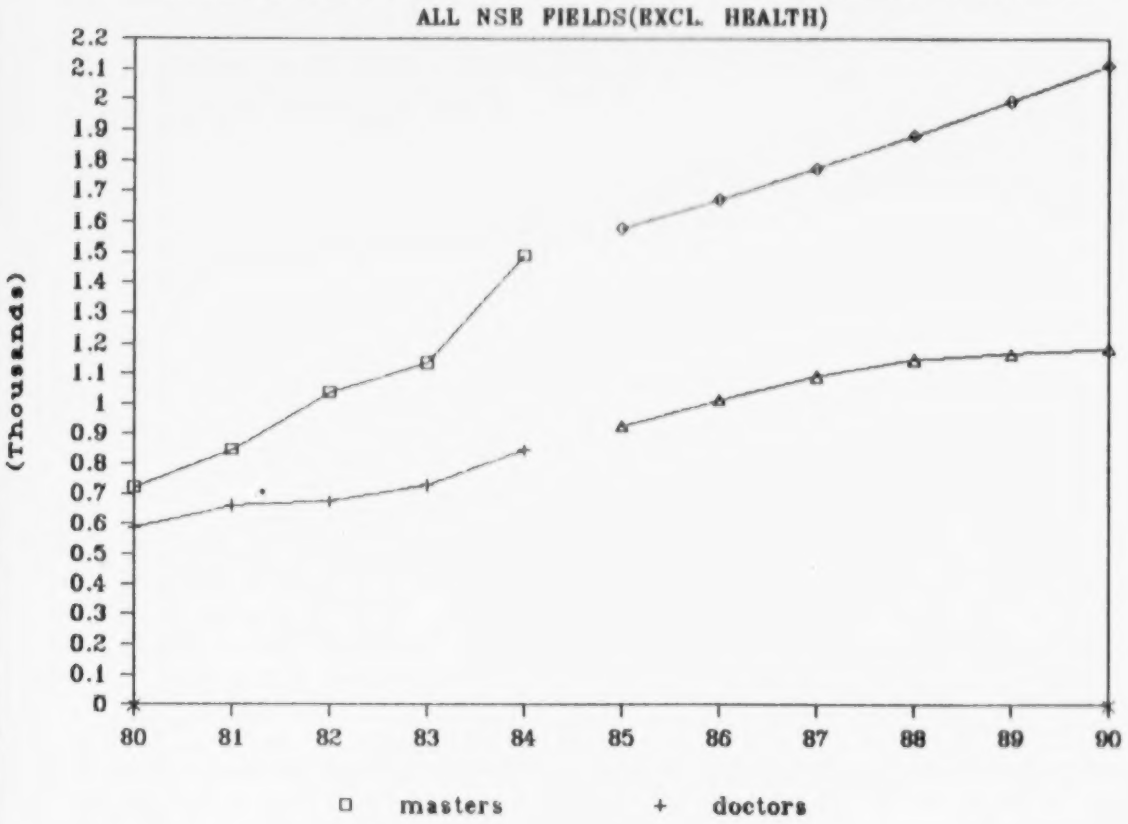
NSERC is the leading provider of training support in Canada. Its programs include encouraging bright undergraduates to pursue postgraduate studies, supporting MScs and PhDs, providing funds for the employment of postgraduate students as research assistants, and supporting post-doctoral training.

The main training program for new researchers is the regular Postgraduate Scholarship Program (PGS), which concentrates on the most highly qualified students. Over the past several years, it has proved to be a flexible program that has grown in response to the emerging demand. From the beginning of the first Five-Year Plan of the Council to 1983-84, the number of regular PGS awards held rose from 1,310 to 2,334. For MScs alone, the number increased by 767 to a total of 1,489 in 1983-84. For PhDs, the gain was 257, to this year's level of 845. (See Appendix Table E-1). It is interesting to note that the biggest gains were in the field of Engineering, particularly at the PhD level. In addition to the regular PGS awards, the Council provides another 400 awards for students at the postgraduate level, including Special, Industrial, 1967 Science and Engineering, and Science Librarianship scholarships. Last year, 21.9% of all full-time Canadian Masters students, and 28.7% of PhD students, held regular NSERC Postgraduate Scholarships.

NSERC also supports a large number of Canadian postgraduate students through its Operating Grants Program. University researchers employ such students as research assistants at a salary rate that is, on a full-year equivalent basis, about 90% of the value of the PGS award. In practice, few students are employed for the full year. Rather, the average operating grant project employs 2 or 3 or even more students, usually only for a few months. As a consequence, up to 2000 Canadian students per year have been supported for at least part of the year through this mechanism. In 1983-84, they represented 20.7% of the full-time students in NSE (excluding Health Professions and excluding foreign students). As holders of PGS awards do not qualify for support through operating grants, the two NSERC programs (i.e., the PGS and the Operating Grants) provide direct support to about

Chart 8

PROJECTION OF PGS AWARDS HELD



Source: NSERC

44.8% of this student population.

It is estimated that the regular PGS awards will increase to 2,115 for Masters, and to 1,185 for PhDs by 1990. (See Chart 8.) This forecast is based on the assumption that success rates for MSc-level applicants will remain at the levels experienced in recent years (43-44%), and will decline for PhD-level applicants (from 53 to 50%); that acceptance rates will remain unchanged for MScs at about 80%, and decline slightly for PhDs from 85% to 80%; and that the percentage of full-time Canadian postgraduates holding PGS awards will rise from 24% to 26%. This includes a significant increase in the relative share of PGS awards held by engineers at both degree levels. (See Appendix Table E-2 for more details on PGS coverage by degree level and field of study.)

Assuming no change in the practice of employing postgraduate students from Operating Grants, the number supported by this program would rise to at least 2,700, or 22% of the full-time NSE students. By 1990, the two Council programs would, therefore, provide support for almost 50% of Canadian postgraduate students.

Problems and constraints

One of the major constraints in closing the manpower gap is that there are not enough qualified students in the pipeline. The number of projected enrolments and degrees is inadequate to meet even the most modest GERD target fully, and this takes into account the growth in the NSERC manpower programs, as described above. The undergraduate population that forms the basis for the postgraduate enrolments over the years to 1990 is enrolled at our universities already, and cannot be increased. Traditionally, only a small percentage of qualified undergraduates in the NSE fields take up postgraduate work. In the short run, efforts are needed to increase the number of undergraduates who will continue their studies at the postgraduate level. The Council's Undergraduate Summer Research Awards program is designed to increase interest among undergraduates in research training. This year, there are some 2,000 such awards that are tenable in university labs, and some 500 in industry labs. The program is projected to grow to 4,000 university and 900 industrial awards by 1990. In the longer term, there will have to be fundamental changes at the lower levels of schooling. As recommended in recent Science Council studies (Science Council, 1982 and 1984. Ferguson, 1982. Orpwood et al., 1984), science teaching will have to be improved and more students, particularly women, must be encouraged to participate in the NSE fields.

Demand is increasing rapidly in some disciplines already, as students react to perceived changes in labour market opportunities. However, the universities find it difficult to expand their capacity in the high-demand fields at an adequate rate. The problem would be aggravated if demand were to grow on a wider basis, as it would under the higher GERD assumptions. This is a troublesome constraint. The age structure of the professoriate militates against the ability of the universities to adapt adequately, and there is no likelihood of significant financial relief in the foreseeable future.

The longer term

The situation at the universities poses a dilemma: the R&D targets cannot be achieved without the universities' fullest participation, and this requires increases in faculty. At the same time, they are not now, nor will they be in the foreseeable future, in a position to expand their faculty. NSERC has implemented several measures to address this situation. One is the University Research Fellowship (URF) program which helps universities increase staff over a limited period of time when they would otherwise not be able to do so on their own. Another is the Industrial Research Professorship program whose major objectives are to train researchers for industry and to establish expertise in new areas of technology of long-term interest to industry. The Council has also proposed a broader, more general scheme to help the universities overcome their current difficulties; this is the NSERC Research Professorship program, which is intended to facilitate the kind of adjustment process that will be so essential for the institutions. The augmentation of the research and training staff of the universities will have to be accompanied by a comparable augmentation of their capacity to support research activities. According to a recent NSERC task force report (NSERC, 1984), this capacity has deteriorated seriously in recent years, and the Council is proposing remedial measures.

More generally, all Council programs contribute to the development of new scientific manpower. Every student, whether or not he receives a scholarship, benefits from the higher quality of the scientific environment at the universities that is created with the help of such NSERC programs as strategic and operating grants, equipment grants, and industrially oriented research grants.

While NSERC's programs are pivotal, they cannot by themselves produce all the new scientists that will be required. HQM

shortages, at least in the short run, will also have to be addressed by more extensive and imaginative use of nonconventional forms of research training. For example, more companies will have to upgrade the research skills of their employees, be they newly-hired B.Sc.s or experienced staff. Under special arrangements with the universities, the practice of providing course work on campus and lab credits in industrial labs should be applied to a much greater extent than is the case now. This would have advantages for both; the universities would enter useful new interactions with industry, and companies, for a relatively modest investment in training, would obtain the qualified researcher of their choice who is fully familiar with their R&D problems and labs.

Traditionally, Canadian industry has performed relatively much less research than its main competitors, and most of the research undertaken has been in short-term, problem solving applications. As a consequence, most research positions are staffed with personnel at the bachelor, rather than the postgraduate, level. To improve its competitiveness and assure its long-term survival, industry will have to pay more attention to fundamental issues, and this requires the deployment of highly-qualified and experienced manpower - - the very manpower that is in short supply. A commitment by industry to long-term research, accompanied by a restructuring of the salary and reward system in favour of research-trained manpower, would have a powerful influence on the attitudes of students at all levels towards an R&D career and would, in the long run, assure an adequate supply of research manpower.

Today's labour market

There remain, today, few job openings for PhDs in the traditional places, such as university teaching and government research. This situation is not going to change until the early 90s when tenured university teachers hired during the expansion phase in the 1960s will retire. Despite this, according to the annual PhD Survey (Statistics Canada, 1985), the unemployment rate for recent PhDs with degrees in NSE fields is relatively low compared to that for people of comparable age with less education. Still, more graduates expect to obtain an academic appointment than can be absorbed into today's academic system, and there are too many whose chosen specialization is not demanded in the labour market and who must find positions in fields and at levels other than for which they are qualified.

The shortfalls projected in this report are certainly not

generated by assumptions about growth in academic positions. On the contrary, if anything, such growth has probably been understated, for fear of expecting too much from the financially strapped universities. Nor do the more plausible scenarios depend on generating large numbers of research jobs in government. The gist of the situation is that, if there are going to be new jobs in research, they will largely be in the private sector in new areas of specialization. Even requirements generated because of attrition in the existing sectors will call for new fields of training. The implications for today's postgraduates are clear: most new jobs will not be in the traditional sectors, and they will require an education that permits more adaptability to change.

APPENDIX A

GERD PROJECTIONS TO 1990

APPENDIX TABLE A-1

PROJECTION OF GERD BY PERFORMING SECTOR TO 1990
(MILLIONS OF CONSTANT 1984 $)

1990 GERD DISTRIBUTION BY PERFORMER: "UNCHANGED 1984"

GNP GROWTH RATE	GERD/GNP RATIO	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
0%	1.24%	1,344	199	2,673	1,070	58	5,344
0%	1.50%	1,620	240	3,222	1,290	70	6,443
0%	2.00%	2,160	320	4,297	1,720	93	8,590
0%	2.50%	2,700	400	5,371	2,150	117	10,738
1.1%	1.24%	1,430	212	2,845	1,139	62	5,687
1.1%	1.50%	1,730	256	3,441	1,378	75	6,880
1.1%	2.00%	2,307	342	4,588	1,837	100	9,173
1.1%	2.50%	2,884	427	5,735	2,296	124	11,466
2.2%	1.24%	1,526	226	3,036	1,215	66	6,069
2.2%	1.50%	1,846	273	3,672	1,470	80	7,341
2.2%	2.00%	2,462	364	4,896	1,960	106	9,788
2.2%	2.50%	3,077	456	6,120	2,450	133	12,235
3.2%	1.24%	1,623	240	3,227	1,292	70	6,452
3.2%	1.50%	1,963	291	3,903	1,563	85	7,804
3.2%	2.00%	2,617	387	5,205	2,084	113	10,406
3.2%	2.50%	3,271	484	6,506	2,604	141	13,007
3.7%	1.24%	1,666	247	3,313	1,326	72	6,623
3.7%	1.50%	2,015	298	4,007	1,604	87	8,012
3.7%	2.00%	2,686	398	5,343	2,139	116	10,682
3.7%	2.50%	3,358	497	6,679	2,674	145	13,353

SOURCE: ESTIMATES BY NSERC

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APPENDIX TABLE A-2

PROJECTION OF GERD BY PERFORMING SECTOR TO 1990
(MILLIONS OF CONSTANT 1984 $)

1990 GERD DISTRIBUTION BY PERFOMER: "ADJUSTED"

GNP GROWTH RATE	GERD/GNP RATIO	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
0%	1.24%	1,122	160	2,939	1,069	53	5,344
0%	1.50%	1,353	193	3,544	1,289	64	6,443
0%	2.00%	1,804	258	4,725	1,718	86	8,590
0%	2.50%	2,255	322	5,906	2,148	107	10,738
1.1%	1.24%	1,194	171	3,128	1,137	57	5,687
1.1%	1.50%	1,445	206	3,784	1,376	69	6,880
1.1%	2.00%	1,926	275	5,045	1,835	92	9,173
1.1%	2.50%	2,408	344	6,306	2,293	115	11,466
2.2%	1.24%	1,274	182	3,338	1,214	61	6,069
2.2%	1.50%	1,542	220	4,038	1,468	73	7,341
2.2%	2.00%	2,055	294	5,383	1,958	98	9,788
2.2%	2.50%	2,569	367	6,729	2,447	122	12,235
3.2%	1.24%	1,355	194	3,549	1,290	64	6,452
3.2%	1.50%	1,639	234	4,292	1,561	78	7,804
3.2%	2.00%	2,185	312	5,723	2,081	104	10,406
3.2%	2.50%	2,731	390	7,154	2,601	130	13,007
3.7%	1.24%	1,391	199	3,643	1,325	66	6,623
3.7%	1.50%	1,682	240	4,407	1,602	80	8,012
3.7%	2.00%	2,243	320	5,875	2,136	107	10,682
3.7%	2.50%	2,804	401	7,344	2,671	133	13,353

SOURCE: ESTIMATES BY NSERC

APPENDIX TABLE A-3

PROJECTION OF GERD BY PERFORMING SECTOR TO 1990
(MILLIONS OF CONSTANT 1984 $)

1990 GERD DISTRIBUTION BY PERFORMER: "RESTRUCTURED"

GNP GROWTH RATE	GERD/GNP RATIO	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
0%	1.24%	670	146	3,408	1,069	52	5,344
0%	1.50%	807	176	4,109	1,289	62	6,443
0%	2.00%	1,076	235	5,478	1,718	83	8,590
0%	2.50%	1,346	293	6,847	2,148	104	10,738
1.1%	1.24%	713	155	3,626	1,137	55	5,687
1.1%	1.50%	862	188	4,387	1,376	67	6,880
1.1%	2.00%	1,149	251	5,849	1,835	89	9,173
1.1%	2.50%	1,437	313	7,312	2,293	111	11,466
2.2%	1.24%	761	166	3,870	1,214	59	6,069
2.2%	1.50%	920	201	4,681	1,468	71	7,341
2.2%	2.00%	1,227	267	6,242	1,958	95	9,788
2.2%	2.50%	1,533	334	7,802	2,447	119	12,235
3.2%	1.24%	809	176	4,114	1,290	63	6,452
3.2%	1.50%	978	213	4,976	1,561	76	7,804
3.2%	2.00%	1,304	284	6,636	2,081	101	10,406
3.2%	2.50%	1,630	355	8,294	2,601	126	13,007
3.7%	1.24%	830	181	4,223	1,325	64	6,623
3.7%	1.50%	1,004	219	5,109	1,602	78	8,012
3.7%	2.00%	1,339	292	6,812	2,136	104	10,682
3.7%	2.50%	1,673	365	8,515	2,671	129	13,353

SOURCE: ESTIMATES BY NSERC

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APPENDIX B

SUPPORTING DATA FOR DEMAND PROJECTIONS

APPENDIX TABLE B-1
GERD (IN CONSTANT 1984 DOLLARS) PER RESEARCHER

(THOUSANDS OF DOLLARS)

	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER
1975	196.0	136.2	176.4	238.5	N/A
1976	189.3	131.4	160.3	232.3	170.0
1977	193.1	127.4	156.9	238.5	168.2
1978	198.9	130.0	159.4	264.0	172.0
1979	186.8	128.0	169.3	238.6	169.2
1980	191.0	138.7	164.6	239.4	170.3
1981	198.9	134.1	174.9	244.7	156.2
1982	200.0	126.7	167.3	242.6	156.2
1983(1)	206.7	131.6	166.1	242.3	166.0
1984(1)	221.8	131.6	166.1	242.3	166.0

(1) 1983 AND 1984: ACTUAL FOR FED. GOV'T; 1976-82 ARITHMETIC MEAN FOR "OTHER" SECTOR; 1975-82 ARITHMETIC MEAN FOR ALL OTHERS

SOURCE: BASED ON DATA FROM STATISTICS CANADA FOR GERD AND RESEARCH MANPOWER (SEE APPENDIX A, AND TABLE 2)

Appendix TABLE B-2

Percentage Distribution of Researchers by Degree and Discipline

	Fed. Gov,t		Prov. Gov't.		Industry		University		Other	
	Degree	Discip.	Degree	Discip.	Degree	Discip.	Degree	Discip.	Degree	Discip.
Applied Sciences and Engineering										
Bachelors	20.0		40.0		55.0		0		0	
Masters	30.0		40.0		35.0		0		0	
Doctors	50.0		20.0		10.0		100.0		0	
Subtotal	100.0	25.0	100.0	25.0	100.0	63.5	100.0	25.0	0	0
Physical Sciences and Mathematics										
Bachelors	20.0		40.0		45.0		0		0	
Masters	30.0		30.0		20.0		0		0	
Doctors	50.0		30.0	25.0	35.0		100.0		0	
Subtotal	100.0	25.0	100.0		100.0	28.0	100.0	25.0	0	0
Agricultural and Biological Sciences										
Bachelors	20.0		40.0		45.0		0		0	
Masters	30.0		30.0		20.0		0		0	
Doctors	50.0		30.0		35.0		100.0		0	
Subtotal	100.0	20.0	100.0	20.0	100.0	6.0	100.0	20.0	0	0
Health Sciences										
Bachelors	20.0		40.0		40.0		0		40.0	
Masters	30.0		30.0		10.0		0		30.0	
Doctors	50.0		30.0		50.0		100.0		30.0	
Subtotal	100.0	30.0	100.0	30.0	100.0	2.5	100.0	30.0	100.0	100.0
TOTAL		100.0		100.0		100.0		100.0		100.0

APPENDIX C

SUPPORTING DATA FOR SUPPLY PROJECTIONS

APPENDIX TABLE C1

FULL-TIME ENROLMENT AND DEGREES GRANTED BY MAJOR NSE DISCIPLINE

	APPLIED SCI. & ENGINEERING				PHYS. SCI. & MATHEMATICS				AGRIC.&BIOLOGICAL SCI.				HEALTH PROFESSIONS			
	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs
YEAR	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.
1971	2,345	994	1,250	191	2,157	879	2,522	447	1,508	498	1,089	247	739	287	728	87
1972	2,192	1,183	1,202	234	2,137	946	2,376	521	1,405	565	1,084	286	653	257	589	93
1973	1,955	1,030	1,178	262	1,947	950	2,157	517	1,144	566	945	276	568	273	527	118
1974	1,955	1,018	1,047	299	1,924	897	1,910	550	1,299	497	933	277	684	291	470	157
1975	2,174	928	986	301	1,984	801	1,745	471	1,283	444	863	240	866	262	435	153
1976	2,431	963	971	227	2,161	821	1,738	414	1,611	473	924	236	923	303	478	122
1977	2,357	1,014	978	188	2,175	853	1,743	379	1,915	593	981	197	1,008	321	474	105
1978	2,383	1,128	950	203	1,983	917	1,670	369	1,889	638	974	228	1,035	363	506	105
1979	2,303	1,150	885	224	1,900	876	1,586	384	1,792	632	952	239	1,207	424	591	125
1980	2,284	1,160	820	231	1,914	798	1,658	318	1,868	574	1,029	224	1,328	470	640	134
1981	2,630	1,109	915	191	1,928	767	1,606	334	1,967	617	1,081	210	1,381	504	675	137
1982	2,843	1,038	966	215	2,258	698	1,677	341	1,983	609	1,147	220	1,506	555	744	113
1983	3,392	1,176	1,162	183	2,411	782	1,878	318	2,109	632	1,232	221	1,578	594	853	150
1984	4,148	1,285	1,363	220	2,708	834	1,914	340	2,197	624	1,316	247	1,808	625	891	160

SOURCE: STATISTICS CANADA: EDUCATION, CULTURE AND TOURISM DIVISION

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Appendix Table C-2

Foreign Students in Full-Time Postgraduate Enrolment

		MASTERS			DOCTORS		
		Total Enrolment (number)	Visa Students (number)	Visa Students as % of Total (%)	Total Enrolment (number)	Visa Students (number)	Visa Students as % of Total (%)
Applied Sciences and Engineering	1978-79	2303	690	30.0	885	296	33.4
	1979-80	2284	714	31.3	820	316	38.5
	1980-81	2630	917	34.9	915	380	41.5
	1981-82	2843	1072	37.7	966	484	50.1
	1982-83	3392	1205	35.5	1162	636	54.7
	1983-84	4148	1175	28.3	1363	702	51.5
Physical Sciences and Mathematics	1978-79	1900	470	24.7	1586	513	32.3
	1979-80	1914	528	27.6	1658	564	34.0
	1980-81	1928	535	27.7	1606	561	34.9
	1981-82	2259	681	30.2	1677	603	36.0
	1982-83	2411	706	29.3	1878	690	36.7
	1983-84	2708	723	26.7	1914	675	35.3
Agricultural and Biological Sciences	1978-79	1792	243	13.6	952	239	25.1
	1979-80	1868	250	13.4	1029	252	24.5
	1980-81	1967	259	13.2	1081	261	24.1
	1981-82	1983	298	15.0	1149	282	24.6
	1982-83	2109	360	17.1	1232	314	25.5
	1983-84	2197	368	16.8	1316	326	24.8
Health Professions	1978-79	1207	119	9.9	591	79	13.4
	1979-80	1328	123	9.3	640	84	13.1
	1980-81	1381	133	9.6	675	110	16.3
	1981-82	1507	153	10.2	748	128	17.1
	1982-83	1578	186	11.8	853	159	18.6
	1983-84	1808	224	12.4	891	165	18.5

Source: Statistics Canada: Education, Culture, and Tourism Division

Appendix Table C-3 (p. 1 of 2)

MASTERS' LEVEL: ENROLMENTS AND DEGREES, ALL NSE FIELDS

	FULL-TIME ENROLMENTS			DEGREES GRANTED		
	TOTAL	CANADIAN & PERM. RES.	TEMORARY VISA	TOTAL	CANADIAN & PERM. RES.	AVAIL. FOR LAB. MKT
1971	6,749			2,658		
1972	6,387			2,951		
1973	5,614			2,819		
1974	5,862			2,703		
1975	6,307			2,435		
1976	7,126			2,560		
1977	7,455			2,781		
1978	7,290			3,046		
1979	7,202	5,680	1,522	3,082	2,482	
1980	7,394	5,779	1,615	3,002	2,402	
1981	7,906	6,062	1,844	2,997	2,365	
1982	8,590	6,386	2,204	2,900	2,268	
1983	9,490	7,033	2,457	3,184	2,442	
1984	10,861	8,371	2,490	3,368	2,502	
1985	10,896	8,696	2,200	3,796	2,813	1,575
1986	11,134	9,034	2,100	4,344	3,348	1,875
1987	11,385	9,385	2,000	4,358	3,478	1,948
1988	11,750	9,750	2,000	4,454	3,614	2,024
1989	12,128	10,128	2,000	4,554	3,754	2,102
1990	12,523	10,523	2,000	4,700	3,900	2,184

Appendix Table C-3 (p. 2 of 2)

PhD LEVEL: ENROLMENTS AND DEGREES, ALL NSE FIELDS

	FULL-TIME ENROLMENTS			DEGREES GRANTED	
	TOTAL	CANADIAN & PERM. RES.	TEMPORARY VISA	TOTAL	CANADIAN & PERM. RES.
1971	5589			972	
1972	5251			1134	
1973	4807			1173	
1974	4360			1283	
1975	4029			1165	
1976	4111			999	
1977	4176			869	
1978	4100			905	
1979	4014	2887	1127	972	
1980	4147	2931	1216	907	606
1981	4277	2965	1312	872	616
1982	4503	3006	1497	889	639
1983	5125	3326	1799	872	617
1984	5484	3616	1868	967	670
1985	5757	3887	1870	1013	678
1986	6029	4159	1870	1153	750
1987	6009	4409	1600	1234	815
1988	6082	4582	1500	1295	877
1989	6200	4700	1500	1357	938
1990	6200	4700	1500	1352	994

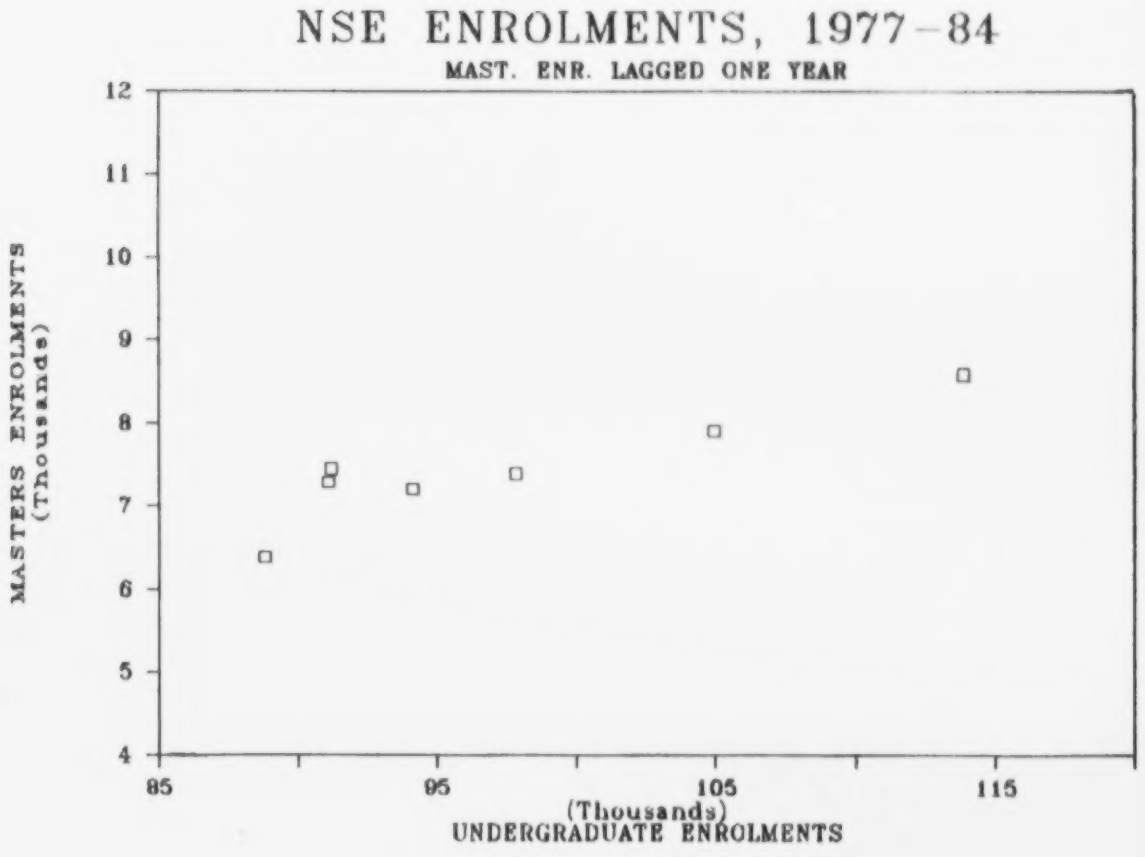
APPENDIX TABLE C-4

SHARE OF DISCIPLINES IN TOTAL NATURAL SCIENCES AND ENGINEERING

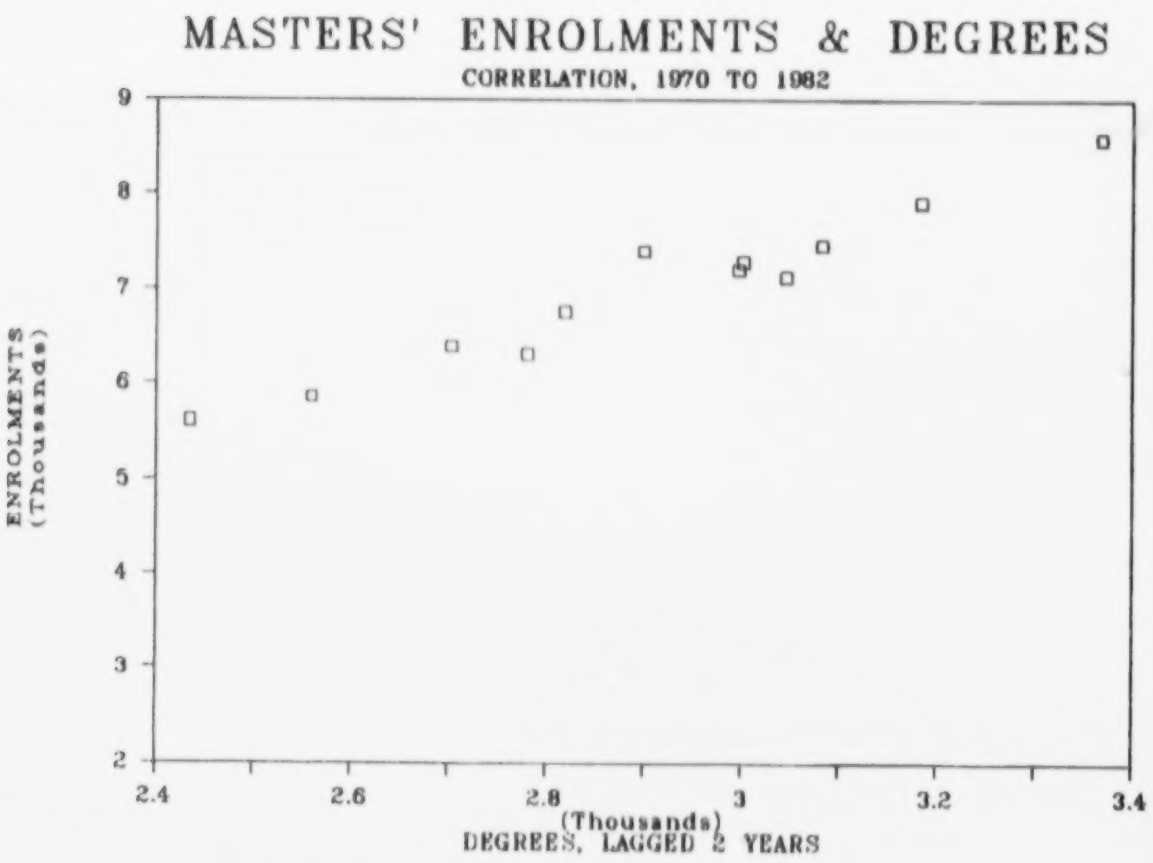
	APPLIED SCI. & ENGINEERING				PHYS. SCI. & MATHEMATICS				AGRIC.&BIOLOGICAL SCI.				HEALTH PROFESSIONS			
	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs	MScs	MScs	PhDs	PhDs
YEAR	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.	ENR'T	DEGR.
1971	34.7%	37.4%	22.4%	19.7%	32.0%	33.1%	45.1%	46.0%	22.3%	18.7%	19.5%	25.4%	10.9%	10.8%	13.0%	9.0%
1972	34.3%	40.1%	22.9%	20.6%	33.5%	32.1%	45.2%	45.9%	22.0%	19.1%	20.6%	25.2%	10.2%	8.7%	11.2%	8.2%
1973	34.8%	36.5%	24.5%	22.3%	34.7%	33.7%	44.9%	44.1%	20.4%	20.1%	19.7%	23.5%	10.1%	9.7%	11.0%	10.1%
1974	33.4%	37.7%	24.0%	23.3%	32.8%	33.2%	43.8%	42.9%	22.2%	18.4%	21.4%	21.6%	11.7%	10.8%	10.8%	12.2%
1975	34.5%	38.1%	24.5%	25.8%	31.5%	32.9%	43.3%	40.4%	20.3%	18.2%	21.4%	20.6%	13.7%	10.8%	10.8%	13.1%
1976	34.1%	37.6%	23.6%	22.7%	30.3%	32.1%	42.3%	41.4%	22.6%	18.5%	22.5%	23.6%	13.0%	11.8%	11.6%	12.2%
1977	31.6%	36.5%	23.4%	21.6%	29.2%	30.7%	41.7%	43.6%	25.7%	21.3%	23.5%	22.7%	13.5%	11.5%	11.4%	12.1%
1978	32.7%	37.0%	23.2%	22.4%	27.2%	30.1%	40.7%	40.8%	25.9%	20.9%	23.8%	25.2%	14.2%	11.9%	12.3%	11.6%
1979	32.0%	37.3%	22.0%	23.0%	26.4%	28.4%	39.5%	39.5%	24.9%	20.5%	23.7%	24.6%	16.8%	13.8%	14.7%	12.9%
1980	30.9%	38.6%	19.8%	25.5%	25.9%	26.6%	40.0%	35.1%	25.3%	19.1%	24.8%	24.7%	18.0%	15.7%	15.4%	14.8%
1981	33.3%	37.0%	21.4%	21.9%	24.4%	25.6%	37.5%	38.3%	24.9%	20.6%	25.3%	24.1%	17.5%	16.8%	15.8%	15.7%
1982	33.1%	35.8%	21.3%	24.2%	26.3%	24.1%	37.0%	38.4%	23.1%	21.0%	25.3%	24.7%	17.5%	19.1%	16.4%	12.7%
1983	35.7%	36.9%	22.7%	21.0%	25.4%	24.6%	36.6%	36.5%	22.2%	19.8%	24.0%	25.3%	16.6%	18.7%	16.6%	17.2%
1984	38.2%	38.2%	24.9%	22.8%	24.9%	24.8%	34.9%	35.2%	20.2%	18.5%	24.0%	25.5%	16.6%	18.6%	16.2%	16.5%

NOTE: THE SUM OF LIKE COLUMNS (e.g. MScs, DEGREES) FOR THE FOUR DISCIPLINES IS 100%

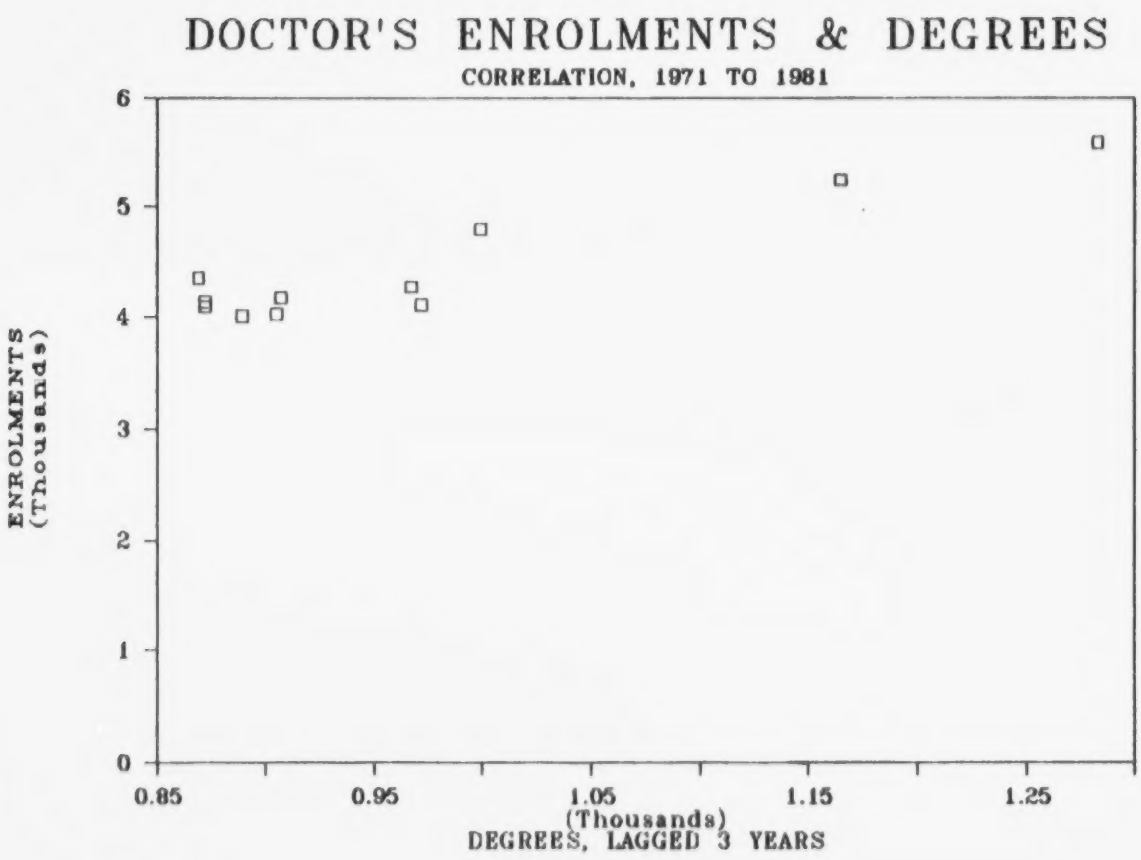
Appendix Chart C-1



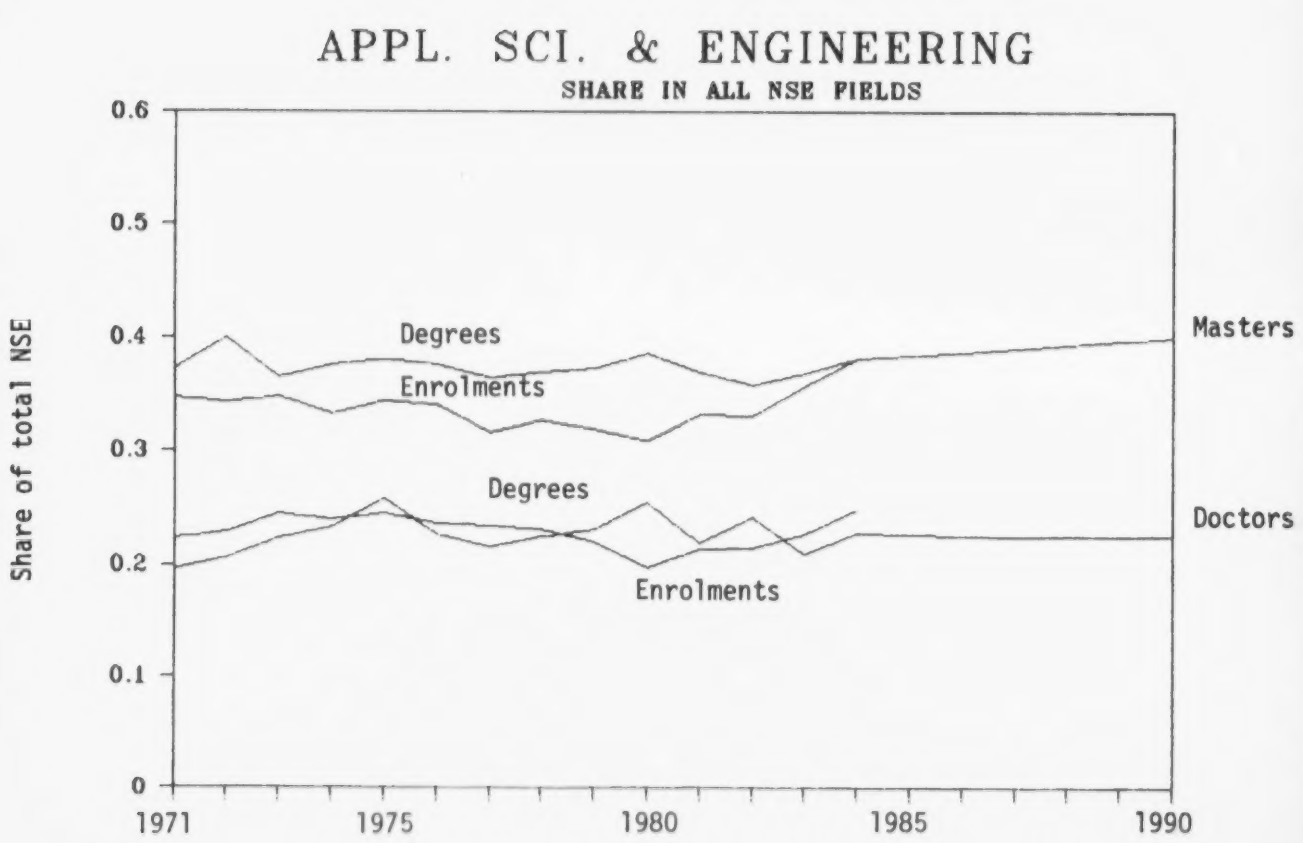
Appendix Chart C-2



Appendix Chart C-3

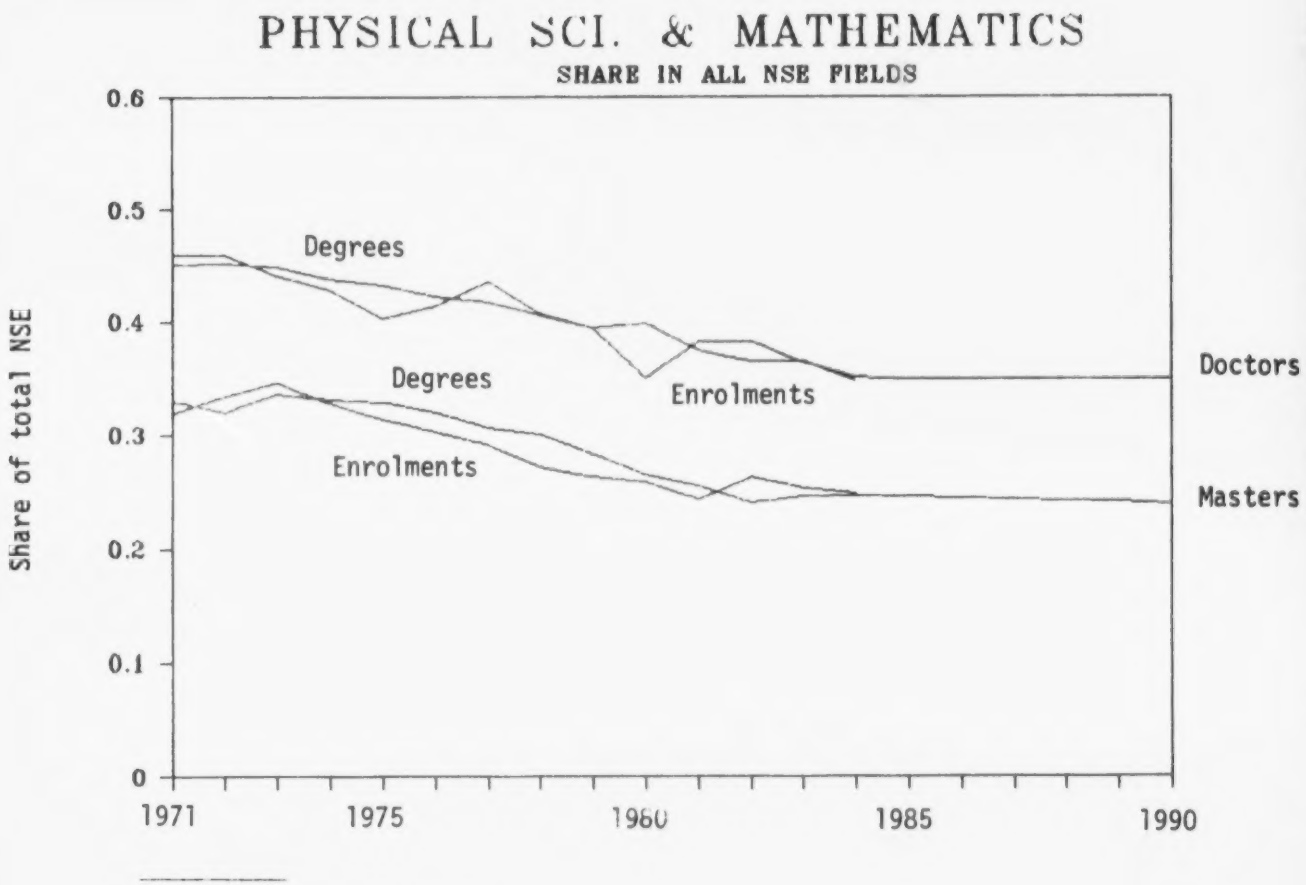


Appendix Chart C-4



Source: Appendix Table C-4

Appendix Chart C-5

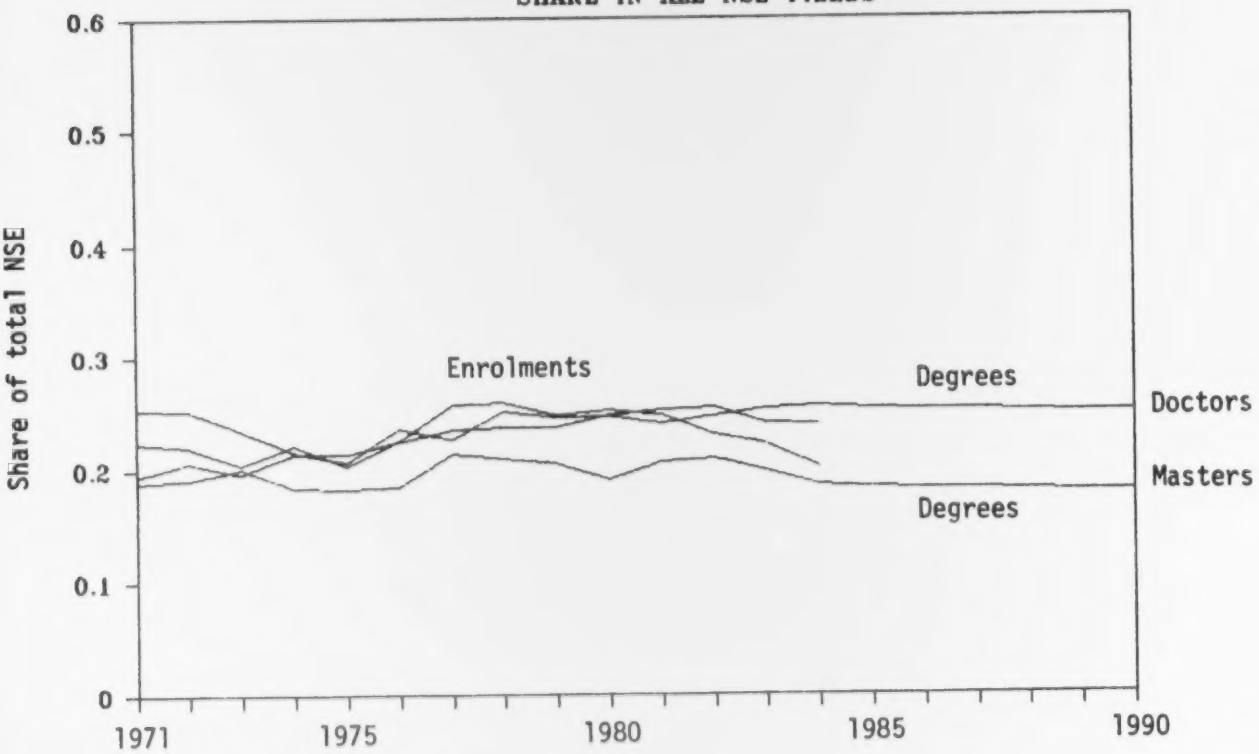


Source: Appendix Table C-4

Appendix Chart C-6

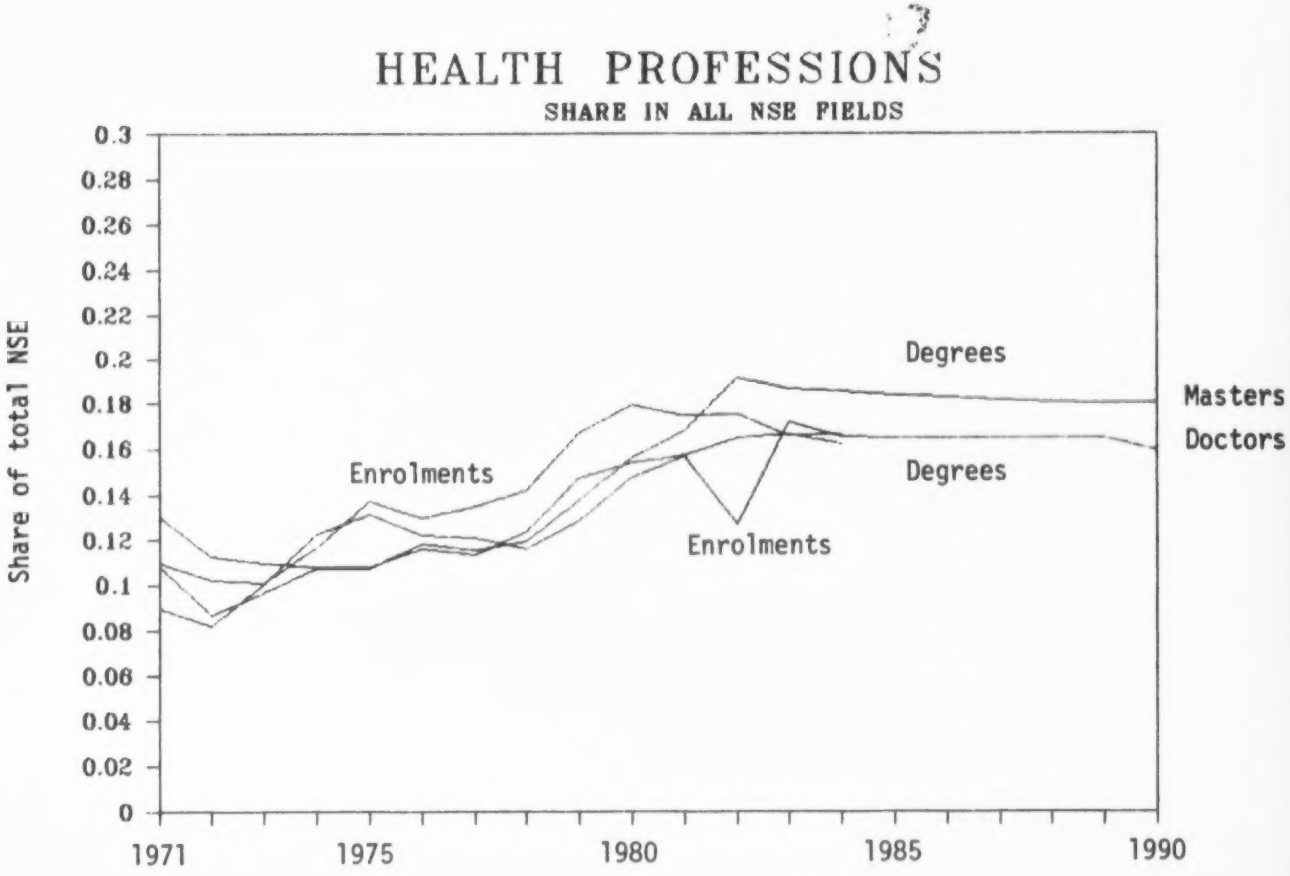
AGR. & BIOLOGICAL SCIENCES

SHARE IN ALL NSE FIELDS



Source: Appendix Table C-4

Appendix Chart C-7



Source: Appendix Table C-4

APPENDIX D

1990 SUPPLY-DEMAND BALANCE BY NSE DISCIPLINE, SELECTED SCENARIOS

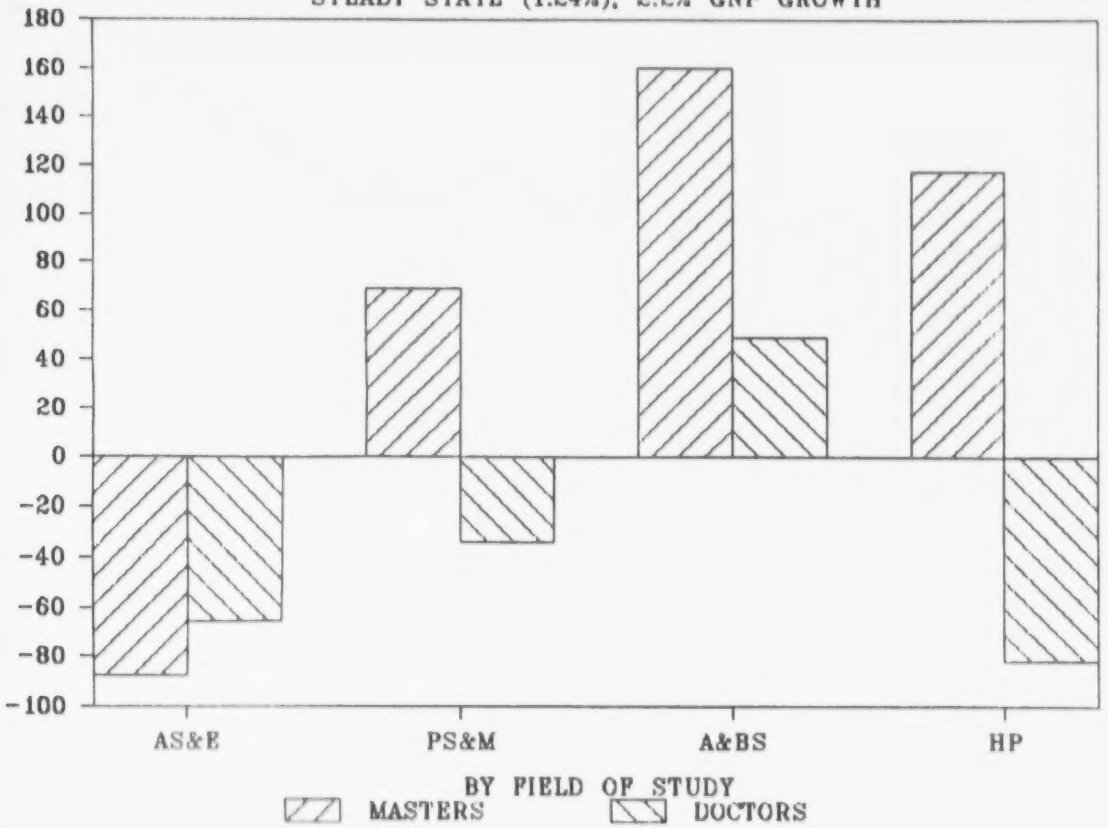
Note on Abbreviations:

AS&E	Applied Sciences and Engineering
PS&M	Physical Sciences and Mathematics
A&BS	Agricultural and Biological Sciences
HP	Health Professions

Appendix Chart D-1

HQM SUPPLY–DEMAND BALANCE, 1984–90

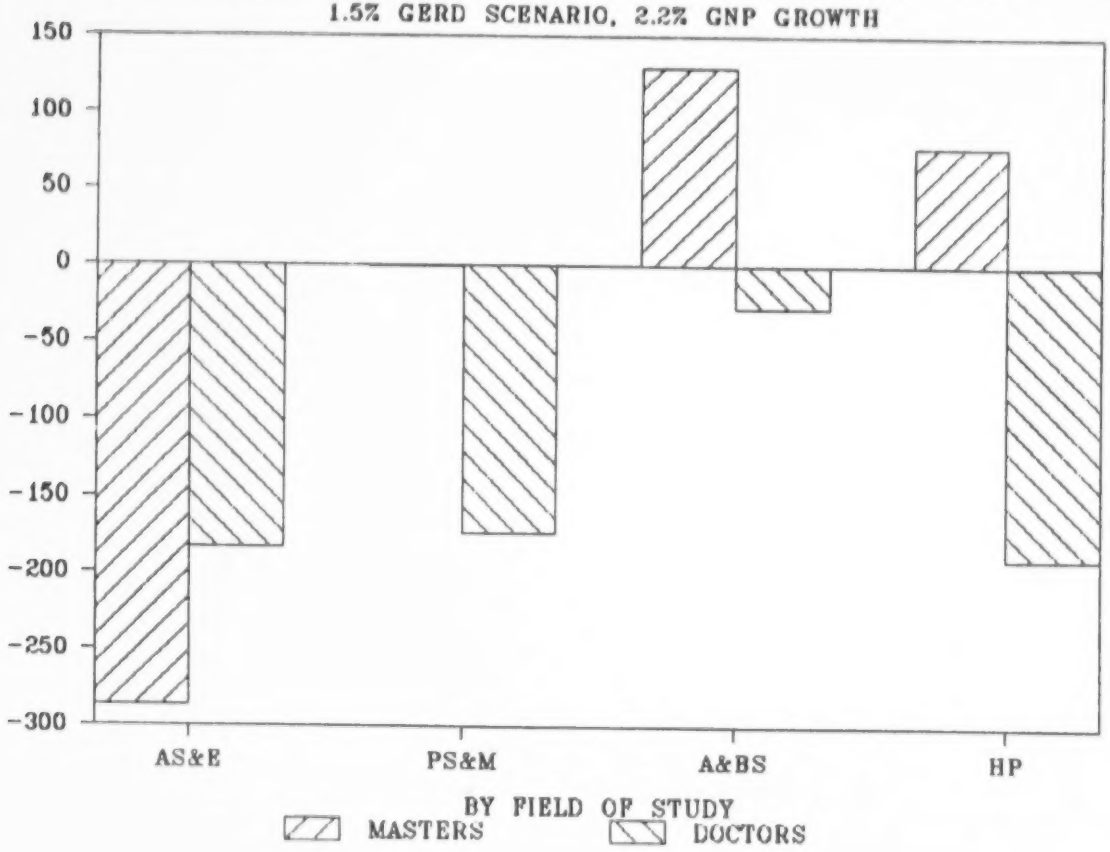
STEADY STATE (1.24%), 2.2% GNP GROWTH



Appendix Chart D-2

HQM SUPPLY–DEMAND BALANCE, 1984–90

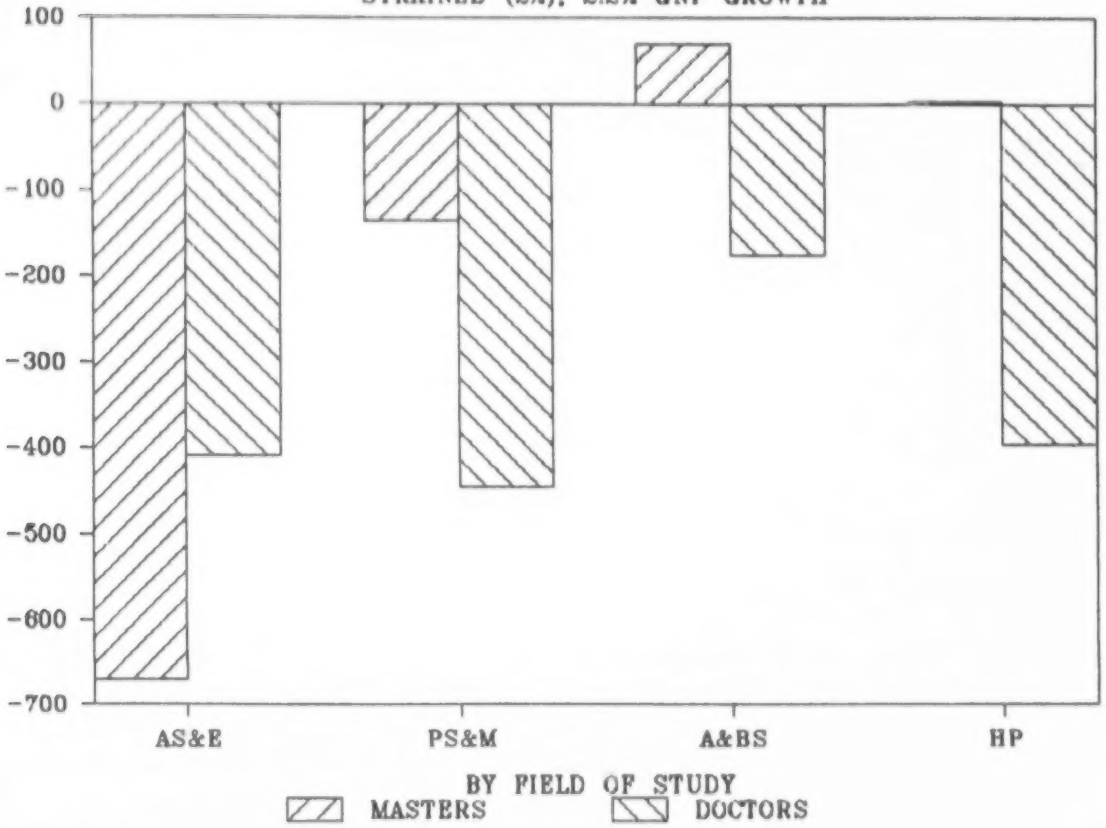
1.5% GERD SCENARIO, 2.2% GNP GROWTH



Appendix Chart D-3

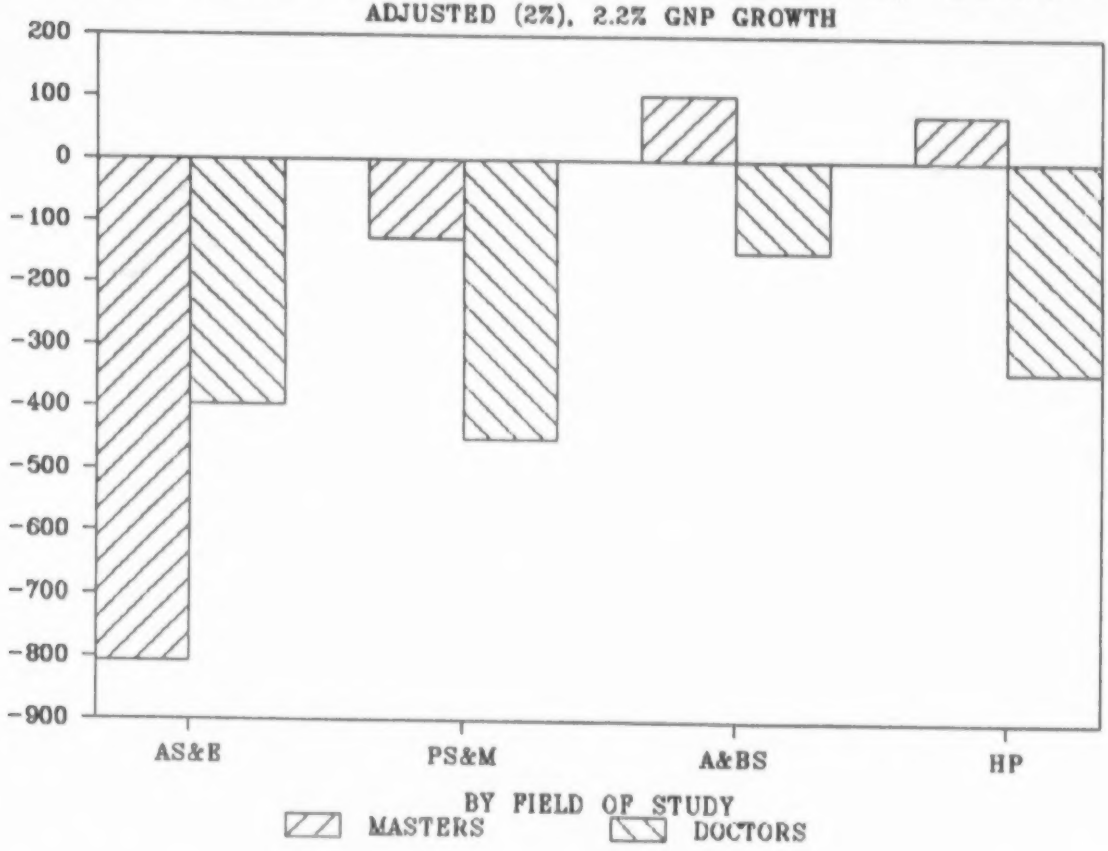
HQM SUPPLY–DEMAND BALANCE, 1984–90

STRAINED (2%), 2.2% GNP GROWTH



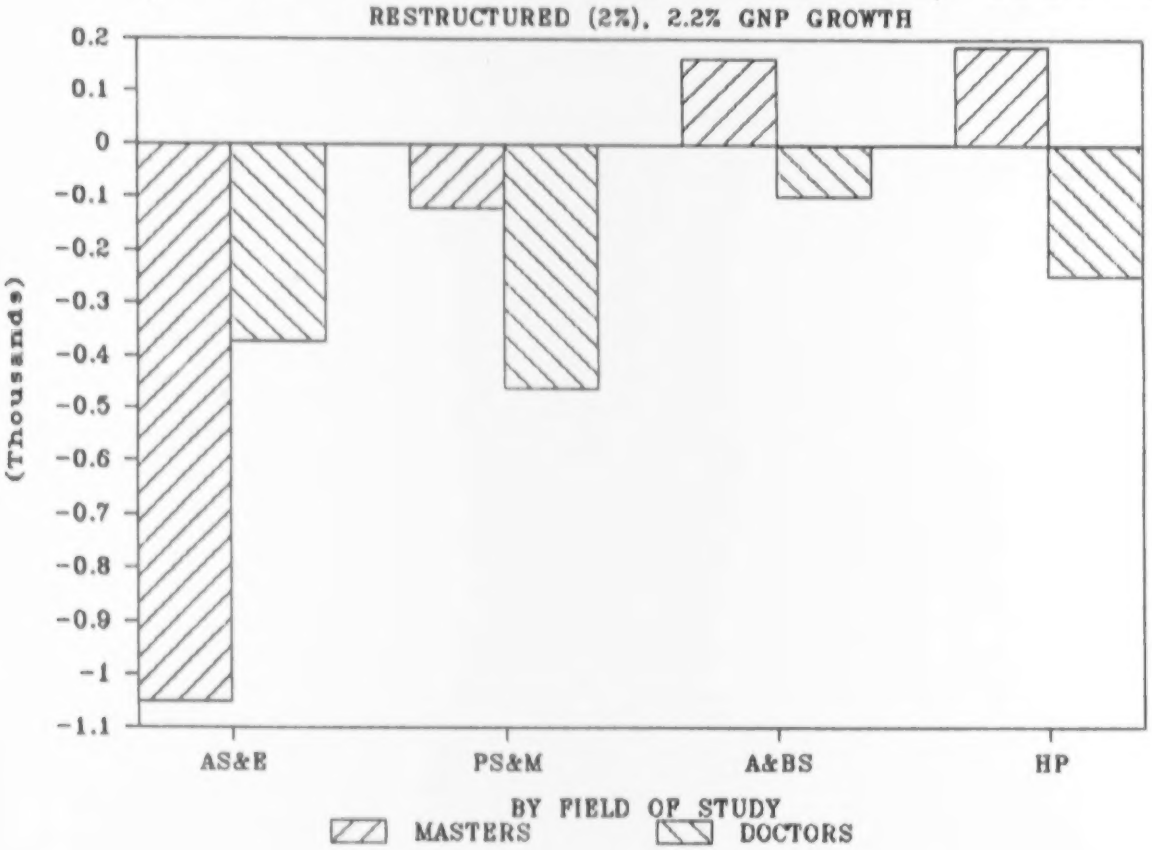
Appendix Chart D-4

HQM SUPPLY–DEMAND BALANCE, 1984–90



Appendix Chart D-5

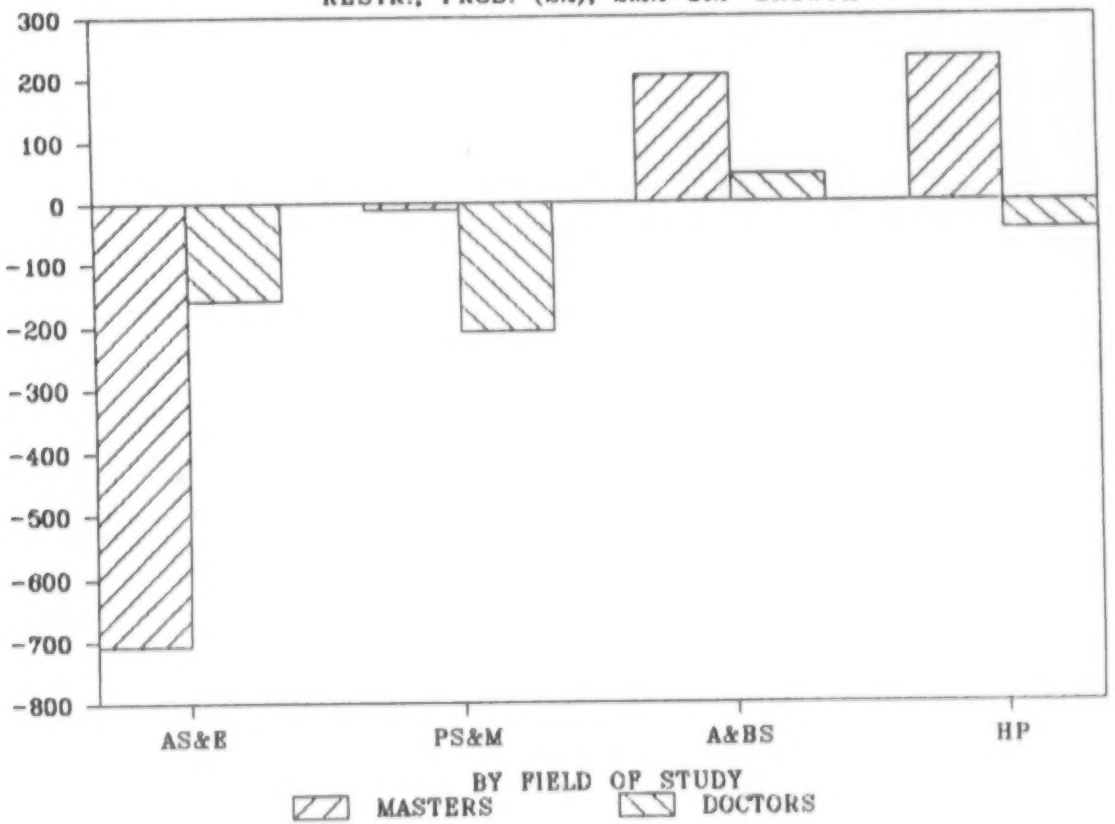
HQM SUPPLY–DEMAND BALANCE, 1984–90



Appendix Chart D-6

HQM SUPPLY–DEMAND BALANCE, 1984–90

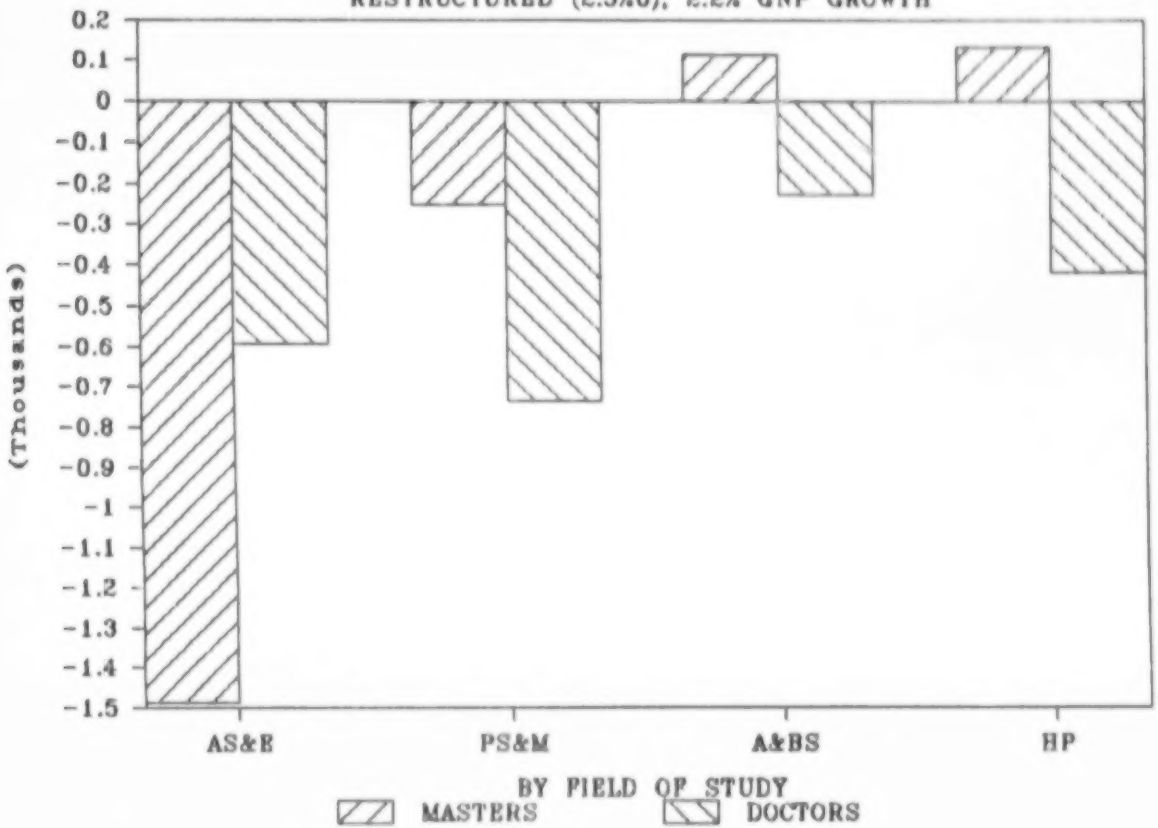
RESTR., PROD. (2%), 2.2% GNP GROWTH



Appendix Chart D-7

HQM SUPPLY–DEMAND BALANCE, 1984–90

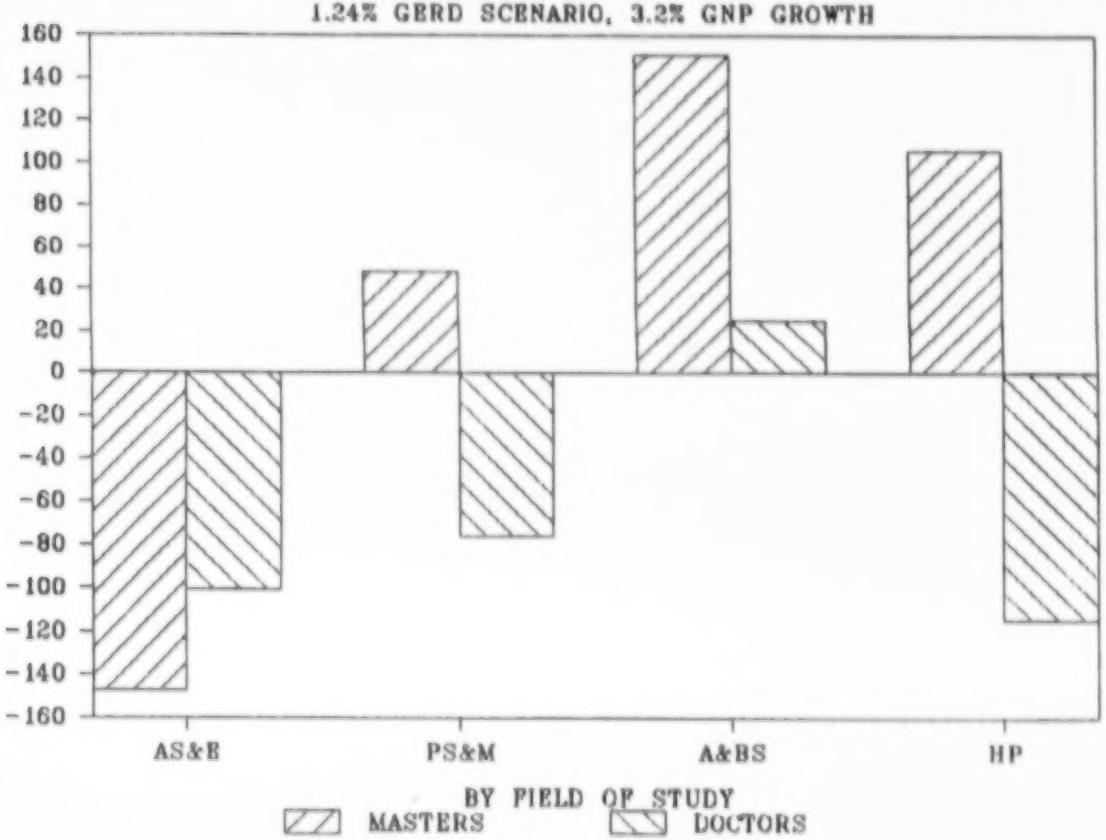
RESTRUCTURED (2.5%0), 2.2% GNP GROWTH



Appendix Chart D-8

HQM SUPPLY-DEMAND BALANCE, 1984-90

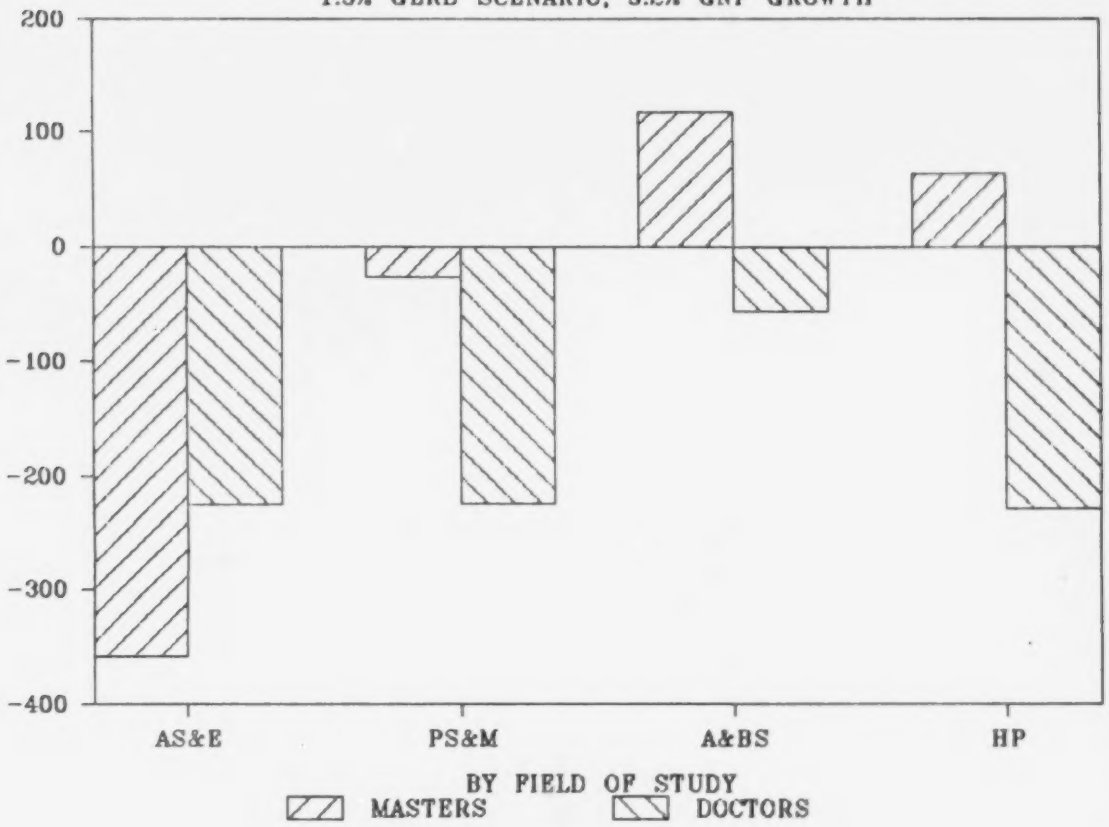
1.24% GERD SCENARIO, 3.2% GNP GROWTH



Appendix Chart D-9

HQM SUPPLY–DEMAND BALANCE, 1984–90

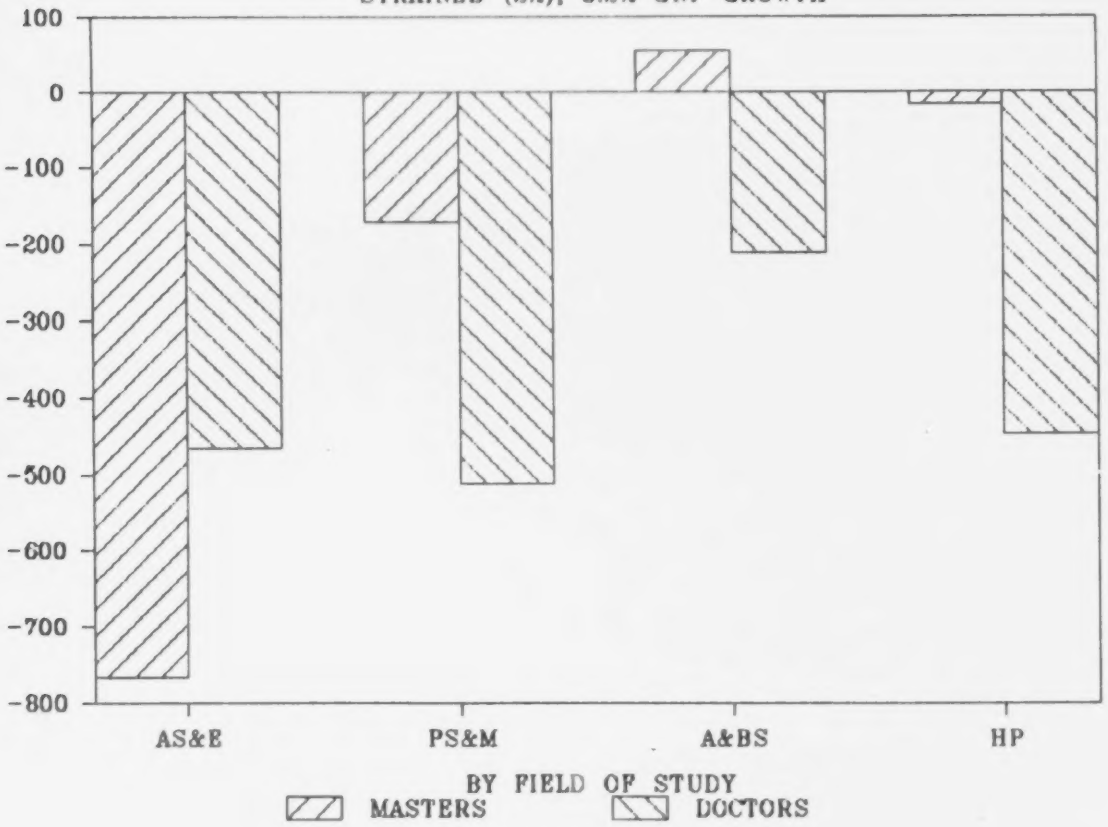
1.5% GERD SCENARIO, 3.2% GNP GROWTH



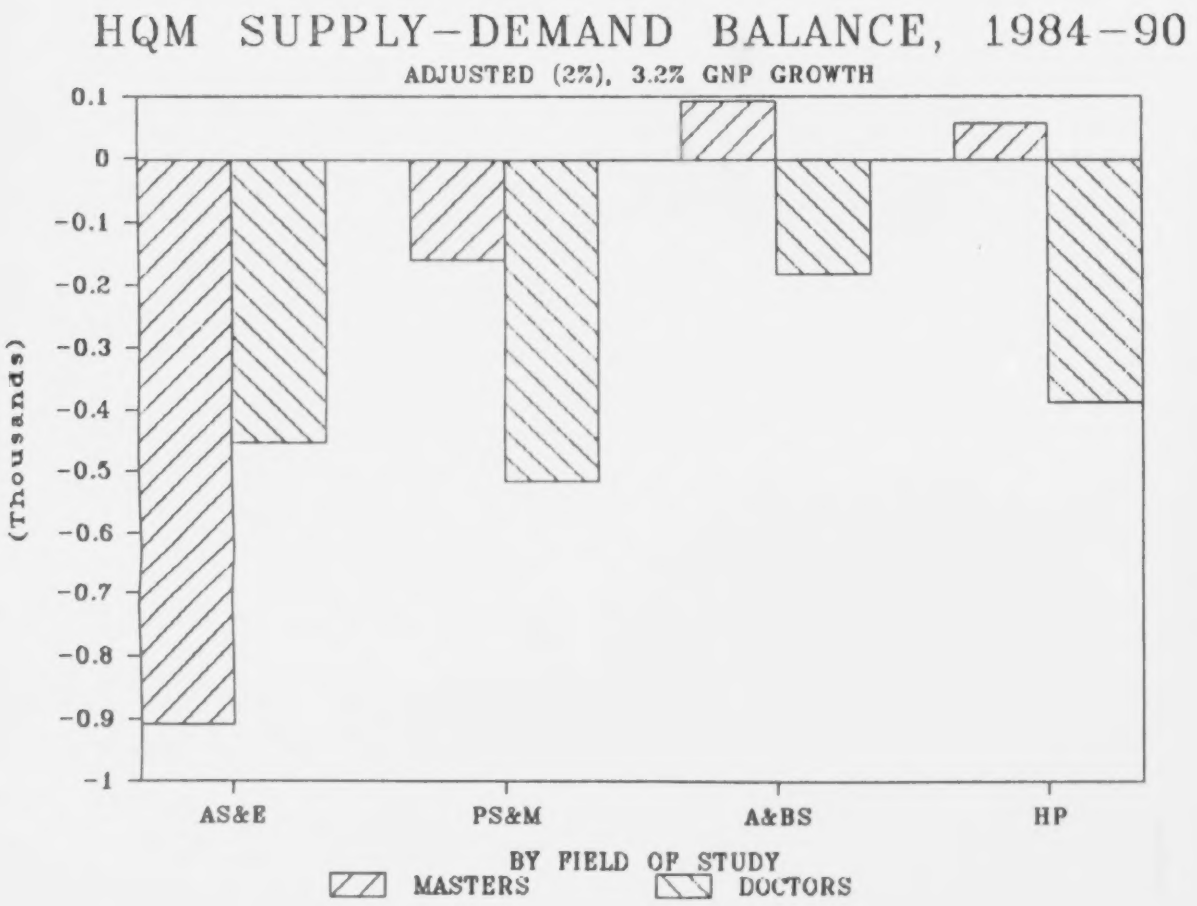
Appendix Chart D-10

HQM SUPPLY–DEMAND BALANCE, 1984–90

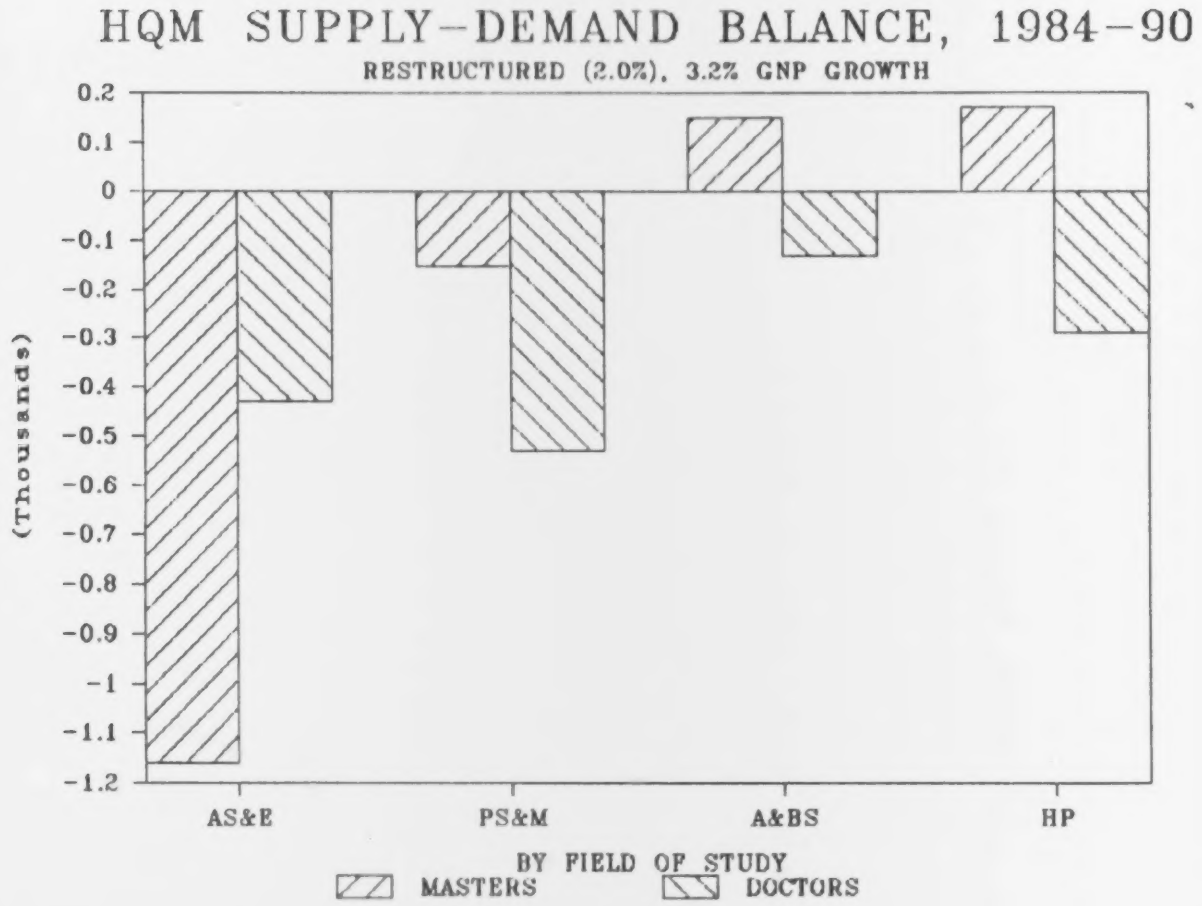
STRAINED (2%), 3.2% GNP GROWTH



Appendix Chart D-11



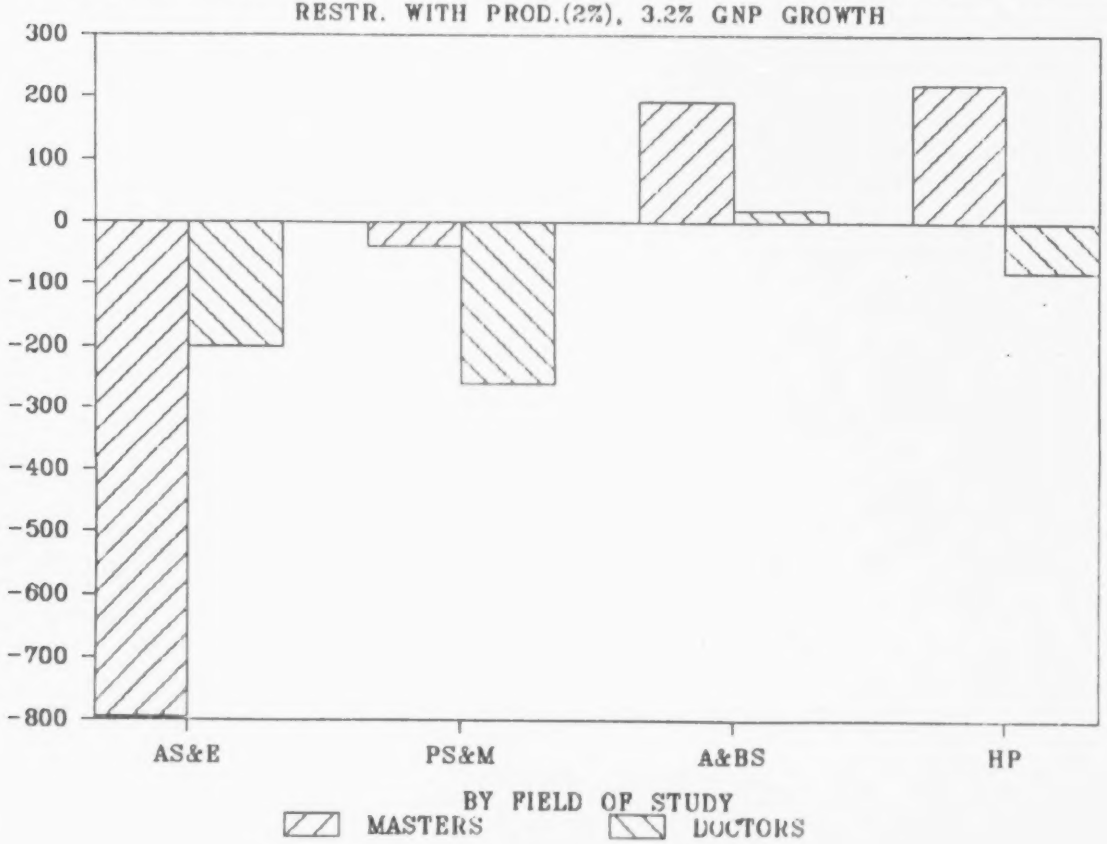
Appendix Chart D-12



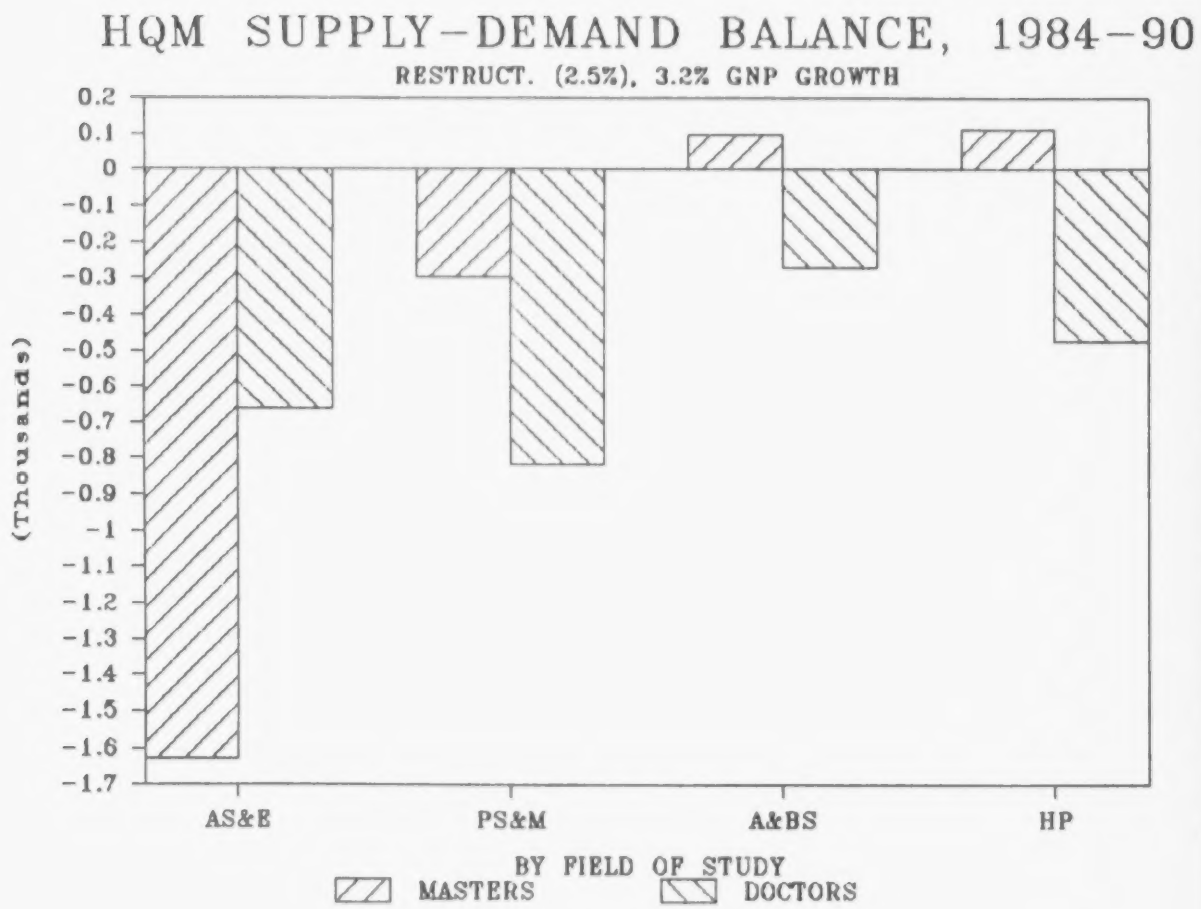
Appendix Chart D-13

HQM SUPPLY–DEMAND BALANCE, 1984–90

RESTR. WITH PROD.(2%), 3.2% GNP GROWTH



Appendix Chart D-14



APPENDIX E

POSTGRADUATE SCHOLARSHIP PROGRAM

Appendix Table E-1

Postgraduate Scholarships (PGS) - Growth

	Applied Sciences and Engineering		Physical Sciences and Mathematics		Agricultural and Biol. Sci.		Total[1]	
1. MASTERS	Number	Index	Number	Index	Number	Index	Number	Index
1979-80	213	100.0	307	100.0	202	100.0	722	100.0
1980-81	245	115.0	350	114.0	254	125.7	849	117.6
1981-82	276	129.6	420	136.8	342	169.3	1038	143.8
1982-83	319	149.8	468	152.4	349	172.8	1136	157.3
1983-84	493	231.5	571	186.0	425	210.4	1489	206.2
2. DOCTORS								
1979-80	74	100.0	294	100.0	220	100.0	588	100.0
1980-81	91	123.0	319	108.5	251	114.1	661	112.4
1981-82	82	110.8	335	113.9	259	117.7	676	115.0
1982-83	114	154.1	329	111.9	285	129.5	728	123.8
1983-84	152	205.4	346	117.7	347	157.7	845	143.7

(1) includes new and reinstated, regular PGS program only

Source: NSERC

Appendix Table E-2

PGS Awards Held as Proportion of Enrolments, by NSE Field

	Percentage of Students Holding PGS Awards	
	1984	1990
Masters		
Appl. Sciences and Engineering	16.6	21.1
Phys. Sciences and Mathematics	28.8	30.3
Agric. and Biological Sciences	23.2	24.4
Total Masters	21.9	24.5
Doctors		
Appl. Sciences and Engineering	23.0	24.3
Phys. Sciences and Mathematics	27.9	29.4
Agric. & Biological Sciences	35.1	36.9
Total Doctors	29.2	30.2
Total Masters and Doctors	24.1	26.3

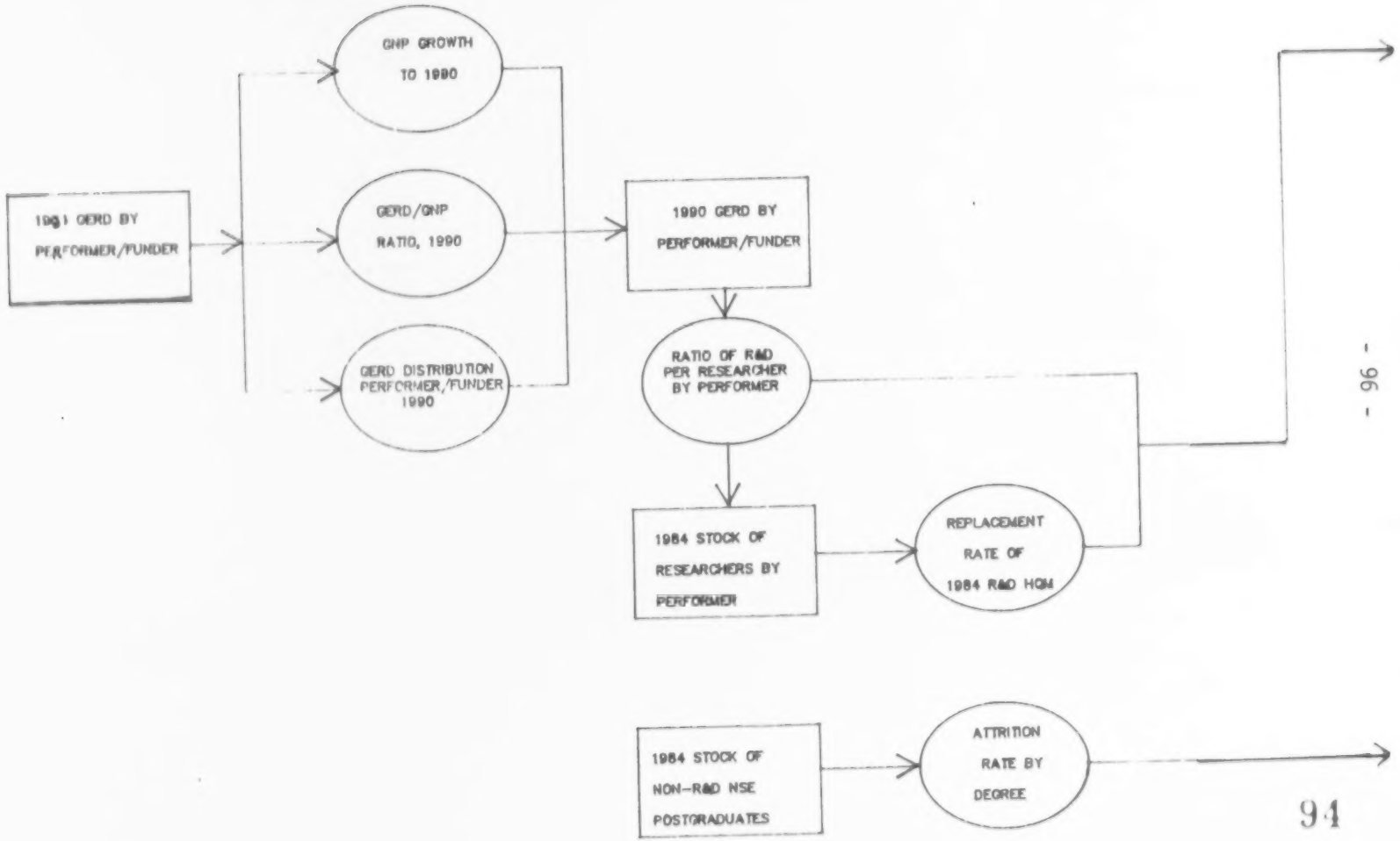
Note: Regular PGS program only

APPENDIX F

NSERC HQM PROJECTION MODEL:

- Model Flow Chart
- Sample print-out of HQM demand calculations

NSERC HQM PROJECTION MODEL (p. 1 of 2)


GNP GROWTH TO 1990
1990 GERD BY PERFORMER/FUNDER
GERD/GNP RATIO, 1990
GERD DISTRIBUTION PERFORMER/FUNDER 1990
RATIO OF R&D PER RESEARCHER BY PERFORMER
1984 STOCK OF RESEARCHERS BY PERFORMER
REPLACEMENT RATE OF 1984 R&D HQM
1984 STOCK OF NON-R&D NSE POSTGRADUATES
ATTRITION RATE BY DEGREE

- 96 -

93

94

NSERC HQM PROJECTION MODEL (p. 2 of 2)

PhD ENROL'T BY DISCIPLINE
UNDERGRADUATE NSE ENR'T
R&D DEMAND 84-90 BY PERFORMER
LAGGED RATIO UNDERGR/MSc ENROL'T
SHARE OF TEMP. VISA STUDENTS
TEMP. VISA STUDENTS
DEGREE/DISCIPLINE DITRIBUTION BY PERFORMER
CANADIAN PhD ENROL'T
LABOUR MARKET AND OTHER
MSc ENR'T BY DISCIPLINE
SHARE OF TEMP. VISA STUDENTS
R&D DEMAND BY DEGREE/DISC. AND PERFORMER
LAGGED DEGREE/ENR'T RATIO
CANADIAN MSc ENR'T
% R&D RELATED DEMAND
CANADIAN PhD DEGREES
MSc DEGREES TO PhD ENR'T
CANADIAN MSc DEGREES
LAGGED DEGREE/ENR'T RATIO
HQM DEMAND BY DEG/DISC.
RATIO OF DISC/TOTAL DEGREES
SUPPLY-DEMAND BALANCE BY DEG/DISC.
HQM SUPPLY BY DEG/DISC
RATIO OF DISC/TOTAL DEGREES
CANADIAN MSc DEGREES TO LAB MKT

NSERC PROJECTION MODEL FOR GERD AND HQM (MARCH, 1985)

(VERSION A: "ADJUSTED" GERD PERFORMER/FUNDER DISTRIBUTION)

		($1984, MILL)
1984 GNP		$429,500
1984 GERD (NSE)		$5,344
1990 GNP (1984-90 GROWTH ASSUMPTION):	3.7%	$534,116
1990 GERD (NSE) (GERD/GNP ASSUMPTION):	2.5%	$13,353

1990 GERD BY PERFORMER AND FUNDER ($1984):

FUNDER: \ PERFORMER:	FED. GOV'T	PROV.GOV'T	INDUST.	UNIV.	OTHER	TOTAL
FED. GOV'T	2,804,060,006	0	738,178,966	986,602,188	11,195,839	4,540,036,999
PROV.GOV'T	0	366,352,723	236,232,197	310,995,520	21,147,695	934,728,135
INDUST.	0	34,209,507	5,843,979,015	124,398,208	6,219,910	6,008,806,641
UNIV.	0	0	0	1,068,207,412	0	1,068,207,412
OTHER	0	0	525,831,225	180,377,402	94,915,833	801,124,459
TOTAL	2,804,060,006	400,562,230	7,344,221,404	2,670,580,729	133,479,277	13,352,903,646

GERD DISTRIBUTION MATRIX, "ADJUSTED" SCENARIO

FUNDER: \ PERFORMER:	FED. GOV'T	PROV.GOV'T	INDUST.	UNIV.	OTHER	TOTAL
FED. GOV'T	21.00%	0.00%	5.53%	7.39%	0.08%	34.00%
PROV.GOV'T	0.00%	2.74%	1.77%	2.33%	0.16%	7.00%
INDUST.	0.00%	0.26%	43.77%	0.93%	0.05%	45.00%
UNIV.	0.00%	0.00%	0.00%	8.00%	0.00%	8.00%	
OTHER	0.00%	0.00%	3.94%	1.35%	0.71%	6.00%
TOTAL	21.00%	3.00%	55.00%	20.00%	1.00%	100.00%

PROJECTIONS OF DEMAND FOR R&D MANPOWER IN THE NATURAL SCIENCES AND ENGINEERING

SUMMARY OF ASSUMPTIONS:

"ADJUSTED" GERD DISTRIBUTION

GNP GROWTH	3.7%	GERD/GNP RATIO	2.5%
R&D/RES.	0%	RAPLACEMENT	35%

1984-90 R&D MANPOWER DEMAND CALCULATIONS:

	FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL
1984 STOCK (R&D,FTE)	6,060	1,512	16,093	4,416	349	28,430
R&D/RESEARCHER	221,800	131,600	166,100	242,300	166,000	
1990 GERD ($1984)	2,804,060,006	400,562,230	7,344,221,404	2,670,580,729	133,479,277	13,352,903,646
1990 STOCK (R&D,FTE)	12,642	3,044	44,216	11,022	804	71,728
STOCK CHANGE 1984-90	6,582	1,532	28,123	6,606	455	43,298
REPLACEMENT	2,121	529	5,633	500	122	8,905
TOTAL NEW R&D DEMAND	8,703	2,061	33,755	7,106	577	52,203

(NOTE: FTE DENOTES FULL-TIME EQUIVALENT PERSON YEARS)

TABLE OF DEGREE BY DISCIPLINE COEFFICIENTS

		FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER
BACHELORS	APPL.SCI.&ENGINEERING	5.000%	10.000%	34.925%	0.000%	0.000%
	PHYS.SCI.&MATHEMATICS	5.000%	10.000%	12.600%	0.000%	0.000%
	AGRIC.&BIOLOGICAL SCI.	4.000%	8.000%	2.700%	0.000%	0.000%
	HEALTH PROFESSIONS	6.000%	12.000%	1.000%	0.000%	40.000%
MScs	APPL.SCI.&ENGINEERING	7.500%	10.000%	22.225%	0.000%	0.000%
	PHYS.SCI.&MATHEMATICS	7.500%	7.500%	5.600%	0.000%	0.000%
	AGRIC.&BIOLOGICAL SCI.	6.000%	6.000%	1.200%	0.000%	0.000%
	HEALTH PROFESSIONS	9.000%	9.000%	0.250%	0.000%	0.000%
PhDs	APPL.SCI.&ENGINEERING	12.500%	5.000%	6.350%	25.000%	0.000%
	PHYS.SCI.	12.500%	7.500%	9.800%	25.000%	0.000%
	AGRIC.&BIOLOGICAL SCI.	10.000%	6.000%	2.100%	20.000%	0.000%
	HEALTH PROFESSIONS	15.000%	9.000%	1.250%	30.000%	30.000%
TOTAL		100.000%	100.000%	100.000%	100.000%	100.000%

BASED ON APPENDIX TABLE B-2

DEMAND FOR HIGHLY QUALIFIED MANPOWER BY DEGREE, DISCIPLINE, AND PERFORMING SECTOR:

		FED. GOV'T	PROV. GOV'T	INDUST.	UNIV.	OTHER	TOTAL R&D SECTORS	R&D REL DEMAND	NON R&D DEMAND	ANNUAL TOTAL
BACHELORS	APPL.SCI.&ENGINEERING	435	206	11,789	0	0				
	PHYS.SCI.&MATHEMATICS	435	206	4,253	0	0	(BACHELOR DEGREES OMITTED FROM HERE ON)			
	AGRIC.&BIOLOGICAL SCI	348	165	911	0	0				
	HEALTH PROFESSIONS	522	247	338	0	231				
MScs	APPL.SCI.&ENGINEERING	653	206	7,502	0	0	8,361	1,672	3,762	2,299
	PHYS.SCI.&MATHEMATICS	653	155	1,890	0	0	2,698	540	1,214	742
	AGRIC.&BIOLOGICAL SCI	522	124	405	0	0	1,051	210	473	289
	HEALTH PROFESSIONS	783	185	84	0	173	1,226	245	552	337
PhDs	APPL.SCI.&ENGINEERING	1,088	103	2,143	1,776	0	5,111		408	920
	PHYS.SCI.&MATHEMATICS	1,088	155	3,308	1,776	0	6,327		505	1,139
	AGRIC.&BIOLOGICAL SCI	870	124	709	1,421	0	3,124		250	562
	HEALTH PROFESSIONS	1,305	185	422	2,132	173	4,218		337	759

NSE POSTGRADUATES: ANNUAL SUPPLY-DEMAND ESTIMATES, 1984-90

SUMMARY OF ASSUMPTIONS:

"ADJUSTED" GERD DISTRIBUTION

GNP GROWTH	3.7%	GERD/GNP	2.5%
R&D/RES(2)	0%	REPLACE. (1)	35%

	MScs SUPPLY	PhDs SUPPLY
APPL.SCI.&ENGINEERING	906	198
PHYS.SCI.&MATHEMATICS	418	294
AGRIC.&BIOLOGICAL SCI.	314	211
HEALTH PROFESSIONS	314	139
TOTAL SUPPLY	1,952	842

	MScs DEMAND	PhDs DEMAND
APPL.SCI.&ENGINEERING	2,299	920
PHYS.SCI.&MATHEMATICS	742	1,139
AGRIC.&BIOLOGICAL SCI.	289	562
HEALTH PROFESSIONS	337	759
TOTAL DEMAND	3,667	3,380

	MScs BALANCE (SHORTAGES IN BRACKETS)	PhDs
APPL.SCI.&ENGINEERING	(1,393)	(722)
PHYS.SCI.&MATHEMATICS	(324)	(845)
AGRIC.&BIOLOGICAL SCI.	25	(351)
HEALTH PROFESSIONS	(23)	(620)
TOTAL BALANCE	(1,715)	(2,538)

(1) R&D CAREER LIFE ASSUMPTION OF 15 YEARS

(2) CHANGE IN CONSTANT DOLLAR R&D EXPENDITURES PER RESEARCHER

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